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Anthony V. Resnik, et al

Federal Water Pollution Administration
Kansas City, Missouri

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ANIMAL WASTE RUNOFF - A MAJOR WATER QUALITY CHALLENGE

ANTHONY V. RESNIK
and
JOHN M. RADEMACHER**

INTRODUCTION

The purpose of this paper is to discuss the causes and effects of animal waste pollution on water quality. Present accomplishments relative to pollution control by regulation are set forth.

The feeding of livestock in confinement has created a new major industry --- having become firmly established in the United States by the late 1950's --- it continues to rapidly expand.

During the emergent stage, designers of cattle feedlots selected sites based primarily on two criteria: drainage and accessibility. The lots were situated on the nearest draw where the rains could scour the waste materials from the lots into nearby gullies and streams. Since, traditionally, animal wastes were considered as "natural" or "background" pollution, control measures were not implemented. In the absence of positive control measures, pollution of the surface waters resulted.

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Now it is known that animal wastes contaminate water supplies, destroy fish and aquatic life in streams, and generally degrade water quality. More important, it is also known that animal wastes are a controllable major source of water pollution necessitating immediate attention.

However, there are still gaps in our knowledge concerning the most efficient, effective and efficacious means of controlling pollution. This will require that we delineate specific research needed relative to the expected trends of the feedlot industry. Not only must this research answer the most pressing present problems, but also must be simultaneously part of long range plans for developing sufficient technology to control feedlot pollution 5, 10, --- 25 years from now. For instance, the interregional adjustments (shifting of location), size, density and other factors are of vital importance in planning research activities. We must, as accurately as possible, project these adjustments.

Prevention and control of animal waste pollution cannot wait while all the data are collected and assembled. To wait for all the answers before taking action would squander time --- time that we do not have. To wait may mean the degradation of many waters beyond the point of recovery --- with accompanying health hazards of undefined proportions ---. To quote Robert H. Finch[1], "echoing Aristole, that the ultimate end --- is not knowledge, but action. To be half right on time may be more important than to obtain the whole truth too late."

Increased control is imperative now. To date, the kaleidoscope of alternatives to animal waste pollution control have been honored more fully in principle than in practice. Feedlot runoff pollution could be greatly reduced with a minimum expenditure by utilizing known information. The majority of feedlot operators have not used techniques which minimize the quantity and strength of runoff waste. For instance, research has shown that feedlot runoff may be reduced by adjusting stocking rates and utilizing optimum feedlot surfaces[2-3].

What does the future portend? Is it possible that animal wastes and city garbage disposal may both be operated on a public utility basis[4]? Furthermore, is this the mechanism to bring together an entire animal production unit to research methods for the utilization of these products?

A much broader view of waste management may be dictated by socio-economic changes. While the return of the wastes to the land may not be competitive with commercial fertilizers on an immediate crop production basis, it may be highly profitable in terms of public welfare over both the short and long range to use these wastes to reclaim marginal lands. We are losing approximately a million acres of agricultural land each year as a result of urban growth, highway construction, and other natural and man-made incursions into the reserve of productive land[4]. It is difficult to equate the true worth to society for the reclamation of lands. Certainly it extends much beyond the yearly crop production.

The residents of the arid and semi-arid regions realize the value of water. Ground water in the semi-arid regions of the Southwest is being mined at an unprecedented rate. For example, in some areas of Arizona the water table is declining as much as 20 feet per year. In many locations the quality of the water deteriorates as the water table lowers. Much of the water now pumped in Central Arizona does not meet minimum agricultural and public health standards[5]. Since the agricultural industry consumes the overwhelming portion of the water used, it has the greatest stake in protecting and enhancing water quantity and quality.

ANIMAL PRODUCTION

There are approximately 110 million cattle in the United States. Dairy cattle outnumbered beef cattle in this country until 1942. Since that time the upward trend in beef consumption, the downward trend in milk consumption per capita, and the upward trend in milk yield per cow have combined to shift this cattle population emphasis to almost four to one in favor of beef -- in just 25 years!

Approximately one-half of the two billion tons of livestock wastes produced annually in the USA comes from animals in confined feeding. The magnitude of the problem caused by feedlot operations is reflected in the statistics for feeder cattle. Data compiled by Loehr[8] show the waste population equivalent of feeder cattle is greater than the human population in each of the 10 Missouri River Basin States.

The Missouri Basin States of Iowa, Nebraska, Colorado, Kansas, Missouri, North Dakota and South Dakota, feed approximately 50 percent of all slaughter cattle. Iowa leads the Nation in the number of cattle and calves on feed. In 1967, more than 4 million beef cattle were marketed from Iowa feedlots.

The majority of the cattle are in small farm feedlots and the average size lot in Iowa feeds less than 70 animals. Only four percent are in feedlots of more than 1,000 head[9].

Nebraska ranks second with approximately 35 percent of the fed cattle in feedlots of more than 1,000 head. Third is California, with an average of 1,800 head per feedlot. There was an 87 percent increase in cattle marketings in California between 1957 and 1963 with virtually all the growth occurring in feedlots with 10,000 head or more capacity. Texas, Colorado and Kansas, respectively, rank fourth, fifth and sixth.

The new glamour area for cattlemen is the Central and High Plains areas including parts of Kansas, Nebraska, Colorado, and the panhandles of Oklahoma and Texas. A recent survey (1968) conducted by the Southwest Public Service Company of Amarillo, Texas, enumerates 274 large commercial feedlots in a 42 county area in Texas, Oklahoma, Kansas, and New Mexico. They have a total one-time capacity of over 1 million head -- 300,000 more than the year before and almost a half-million more than in 1966[10].

The Texas High Plains has become the center of the rapidly expanding fed cattle industry in Texas experiencing a remarkable 146 percent increase in cattle inventories between 1965 and 1968. Fed cattle inventories for the State increased 66 percent in the same three year period. The exceptional growth of the fed cattle industry on the High Plains is attributed to an availability of feed, adequate supplies of feeder cattle, an adequate transportation network, rapid growth of irrigation wells, and a favorable climate. Livestock feeders state that cattle performance is better at higher elevations where summer nights are cool and humidity is low[11].

Surveys reported by Colorado, California and USDA during the early growth of the commercial feedlot indicated that optimum feedlot capacity ranged between 10,000 and 20,000 head. Today 30,000 head capacities are routine with 40,000 - 70,000 head lots becoming more prominent in the panhandle area of Texas. Thus, it becomes apparent that growth is still a part of this industry[13]. It has been estimated that by the early 1970's, approximately 2,500 large commercial feedlots in the United States will supply nearly 70 percent of all the Nation's finished cattle[10].

There does not appear to be an optimum size feedlot. The continuous decline in costs with increases in size seem to justify continued increases in the size of the lots. However, additional studies considering both internal and external costs of operation are needed[12]. Studies to date have largely dealt with internal costs --- tax benefits, buying advantages, and other external factors have not been fully evaluated.

COMPOSITION AND QUANTITY OF RUNOFF

The runoff from cattle feedlots can be potent. Miner, et al,[3] reported COD concentrations from 3,000 to 11,000 mg/l, ammonia nitrogen concentrations ranged from 16 to 40 mg/l and suspended solids ranged from 1,500 to 12,000 mg/l.

These data provide a basis for an example of the significant difference between population equivalent (PE) values based on runoff and values based on manure production[10-14].

The oft cited PE values based on total animal production have little meaning with regard to water pollution. What we are really concerned with is the amount that enters ground and surface waters. If the objective is to quantify the magnitude of the potential stream pollution, PE values should be based on the strength and volume of wastes which can enter a stream by storm water runoff rather than the total manure production. Dague[14] cites calculations, for a given set of conditions, which demonstrate the BOD actually contributed to the stream is about five percent of the total BOD production of the animal.

Other investigators have, using developed models, made estimates of the total annual pollution loads generated by runoff from feedlots. These investigators also demonstrated the quantity and strength of the wastes which enter the streams to be considerably less than that defecated by the animals. Let us now attempt to place this problem into perspective.

Sixty six thousand feedlots, ranging in capacity up to 100,000 animals blanket 7 of the 10 Missouri Basin States. Animal wastes --- from the more than 20 million cattle, 16 million swine and 7 million sheep defecate wastes equivalent to 370 million people. Using the previously cited 5 percent figure, then the magnitude of the stream pollution from animal wastes is more than 18 million PE in the Missouri River Basin. The human population of the Missouri Basin Region is 7.9 million. Thus, the calculated stream pollution from animal wastes is more than twice the human population equivalent.

We must use caution in predicting and interpreting stream pollution from feedlots. There are many variables which influence the effect of feedlot runoff upon the receiving water course. Among these factors are the climate of the region and the area and nature of the feedlot surface. Also, the antecedent moisture condition of the accumulated waste and the rate at which precipitation occurs are of primary importance in determining the quantity and quality of runoff from a feedlot[2]. It has been noted by various investigators[2-10] that the greatest pollutant concentrations are obtained during warm weather, during periods of low rainfall intensity, and when the manure has dissolved by water soaking.

During warm, dry weather, especially in the semi-arid regions, the most noticeable change in the deposited manure is evaporation of moisture. The wastes become ground and pulverized by the hooves of cattle. If the accumulated waste on the feedlot floor becomes tightly compacted and dry, it provides a relatively imperious barrier to the initial rain resulting in large quantities of organic runoff. However, if the accumulated manure on the feedlot floor is slightly damp when precipitation begins, it can readily absorb a large quantity of rainfall at a rapid rate, resulting in lesser amounts of runoff during the early stages of the precipitation.

The dry, high altitude of the Texas High Plains provides excellent drying conditions for the huge quantities of feedlot wastes. During the summer months, the moisture content of the finely pulverized dehydrated feces and urine solids may go as low as 2 percent[2].

It must be remembered, however, that generalizations concerning feedlot runoff are necessarily lacking in precision. For example, weather conditions alone can be quite important. Data reported by Kansas State University indicated all pollutional parameters greatly exceeded previously measured values during a heavy rainstorm with lot surfaces wet when the rain began. Three inches of precipitation fell during an eight hour period. Suspended solids were 26,850 mg/l in samples taken 2-1/2 hours after the storm began and 4 hours later were 45,200 mg/l[10].

EFFECT OF ANIMAL WASTE POLLUTION ON WATER QUALITY

Since feedlots have generally been located without regard to the soil inventory and topographic characteristics, surface runoff to streams with subsequent damage from high BOD wastes is common. Infiltration of nitrates from manures to well waters is well documented[6-7]. Field disposal of large concentrations of manures can lead to contamination of underground supplies.

Field investigations of fish kills and other water pollution episodes substantiate that the degradation of water quality due to animal wastes is indeed a serious matter. The release or runoff of these wastes to surface streams during periods of rainfall runoff produces "slug" loads of the polluting material which can traverse the receiving stream for many miles, kill all desirable aquatic life in its path, disrupt or prohibit the use of the affected stream for water supply purposes, and generally create public alarm[15].

The slug flow and resultant adverse effects of animal wastes can be felt hundred of miles from their point of entry. Spring rains in Kansas in 1967 washed tons of cattle feedlot wastes into receiving streams resulting in fish kills and ruining the water supply of downstream towns[16].
The Missouri Water Pollution Board conducted dissolved oxygen analyses of the Missouri River in June and July of 1967 during and after a fish kill in the River. The following data were obtained[16]:

> Kansas City, Missouri - The dissolved oxygen level dropped to 1.5 mg/l in the river water, and was less than 4 mg/l for 11 days, and did not reach 5 mg/l for 19 days.
>
> St. Joseph, Missouri - At times, the dissolved oxygen level was virtually zero and was less than 4 mg/l for 7 days, and did not reach 5 mg/l for 15 days.
>
> Jefferson City, Missouri - The dissolved oxygen content dropped to 2.1 mg/l and was less than 4 mg/l for 7 days and remained less than 5 mg/l for almost a month.

The flow in the Missouri River at all three stations ranged from approximately 80,000 to 260,000 cfs with an average of 180,000 cfs at Kansas City. Based on the above flows and dissolved oxygen deficiencies, the oxygen demand was equivalent to the waste BOD from 80 to 120 million people. Approximately 3 million population equivalent is the maximum that can be accounted for from municipal and industrial sources[16]. Animal wastes are one of the prime suspects for the large unaccountable pollution load.

Surface water supplies in Kansas have been seriously disrupted by feedlot runoff pollution. One such incident is described by an Official[17] of the Kansas State Department of Health.

> "In 1967 one small Kansas community using surface water as a supply source was forced for a period of two weeks to treat water with the following characteristics: ammonia content up to 20 mg/l; BOD_5 up to 75 mg/l; dissolved oxygen 0.0 mg/l; total coliform count 4 million; fecal coliform count 2 million, and total fecal streptococcus count at 5 million per 100 m/l sample. Additionally the water was heavily loaded with pungent and difficult-to-describe organic materials which produced a finished water product highly offensive to the senses of taste and smell. The city was forced to use activated carbon and increase chlorination by a factor of 10 in order to not-too-successfully continue operation of the water treatment plant[17]."

There is additional evidence that animal wastes are a major source of water quality degradation. During the past year, an estimated 12 million fish were killed by pollution in our waters. This terrible toll reflects only the actual kills discovered and reported. Many more thousands of dead fish go unnoticed or unreported each year[18]. Thirty six fish kills in Kansas streams were investigated by the Kansas State Department of Health and the Forestry, Fish and Game Commission during 1967-1968. Twenty two of these were attributed to runoff from commercial feedlots[19]. Spring rains in Kansas in 1967 washed tons of cattle feedlot wastes into the receiving streams killing an estimated

500,000 fish. This is not to say that fish kills are unique to Kansas, but rather suggests a greater awareness by Kansas officials of the pollution caused by animal wastes[8].

Another example -- recently, in Kansas, a large dairy herd was decimated after drinking from a well polluted by the runoff from beef cattle waste. This dramatically illustrates the serious contamination that can be caused by uncontrolled animal wastes[8].

Animal waste pollution is not restricted to the Midwest; it is a national problem. In early 1966, the Interstate Commission on the Potomac River Basin reported[20]:

> "Every time it rains ... enormous amounts of animal wastes are washed from farmyards into the river, rendering it unsafe for swimming .. although only a quarter-of-a-million people live in the river basin above Great Falls, it has been estimated that the number of farmyard animals -- cows, sheep, pigs, chickens, turkeys -- is the equivalent of a human population of 3.5 million. While most of the human population is served by some sort of sewage treatment plant, there is no comparable treatment for the animal wastes."

Still another affected area is in the great Southwest. For example, the residents of Milford, Texas, have brought numerous damage suits involving pollution against a large feedlot located a mile from the community[21]. The rapid growth of the fed cattle industry in the semi-arid lands of the Southern and High Plains areas has resulted in the concurrent development of a major water pollution problem.

Numbers of cattle on feed and feedlots with a capacity of 1,000 head or more increased five-fold within the Southern Plains since the mid 1950's[2]. The problem starts with the cumulative build-up of large quantities of organic waste on cattle feedlots subjected to sporadic and intense rainfall. Evaportation rates are high in summer and the limited rainfall (15-20 inches annually) comes in sporadic bursts over short time periods and unless controlled, this runoff will enter the water courses.

One of the most pressing needs in water pollution control is to slow the eutrophication of lakes (aging process) which is accelerated by overenrichment due to agricultural, industrial and municipal wastes. Lake Erie is the most dramatic -- and potentially tragic -- example of oxygen depletion in the water caused by nuisance aquatic plants filling the lake. Many other lakes -- large and small -- are in the same desperate condition but have not achieved the national recognition afforded Lake Erie.

Although other nutr-ent sources such as municipal sewage and industrial discharges are big contributors to eutrophication, the vast amount of manure being produced in this country is one of the major causes of the killing of a lake or river by accelerated eutrophication[22]. Nitrates and phosphates cause eutrohpication, and manure contains both of these plant nutrients. They can be carried by runoff into the streams or percolate through soils to enter the waterways.

In Minnesota, attention to the problem of eutrophication was brought forth by the study on the Big Stone Lake where preliminary investigations indicate a large amount of the nutrients entering the lake is from cattle feedlots. The Minnesota Pollution Control Agency stated "there are places in the country where three or four times as much raw sewage enters our streams from animals as from human beings[23]."

Studies on Lake Mendota near Madison, Wisconsin, points the accusing finger at manure carried by spring runoff into the lake as the source of unwanted nutrient enrichment and growth of water plants. Limnologists see eutrohpication taking place in other beautiful lakes in Minnesota and other states[24].

EFFECT OF ANIMAL WASTES ON GROUND WATER

In a statewide survey the University of Missouri analyzed more than 6,000 water samples in Missouri. Forty two percent of the water samples contained more than 5 parts per million as nitrogen nitrate[25]. In come counties in Northwest Missouri, over 50 percent of the wells sampled contained sufficient nitrogen to be of concern in livestock production. Data obtained indicated animal manure to be one of the major sources of nitrate in water supplies. There was a definite statistical relationship between livestock numbers and shallow wells containing nitrate.

Agriculture's effect on nitrate pollution of ground water was also investigated in the South Platte River Valley of Colorado. Most of the 621,000 cattle in Colorado feedlots (February 1, 1967) were located in this valley. Data obtained showed that nitrate under feedlots is moving through the soil and into the ground water supply. Since the feedlots are usually located near the homestead, they may have a pronounced effect on the water quality from domestic wells. The findings that water under feedlots frequently contained ammonium and organic carbon cause further concern about the effect of feedlots on underground water supplies[26].

ACCOMPLISHMENTS: KEYS TO THE PROBLEM

The culmination of comprehensive Federal water pollution control legislation came with the enactment of the Federal Water Pollution Control Act, Public Law 660, in 1956. This law is the basis for the Federal role and responsibility in water pollution control and prevention and stresses the recognition of the State responsibility in water pollution control. The amendments represented by the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966 were extensive and far reaching.

The official state enforcement agencies are assuming their responsibility in animal waste control. For example, eight of the 10 Missouri River Basin States have enacted or are now in the process of enacting, feedlot regulations. Regulations are, in effect, the blueprints for the animal waste control program. They act as a guide to planning, construction and enforcement. Regulations are needed to ensure the feedlot operator that the measures he is taking will guarantee a reasonable tenure of operation. It is necessary that the operator know the controls being installed are adequate, and secondly, that frequent changes will not be sought by the official agency. Uniformity which concurrently allows for flexibility must be built into the regulations. Different requirements may constitute an economic barrier and are especially confusing to operators conducting business in two or more states.

The existing legislation pertaining to feedlot pollution control should be thoroughly evaluated. Many of the basic concepts contained in the regulations are sound. However, more attention should be directed to management practices which would prevent the wastes from entering surface or ground waters.

For instance, the percent removal concept of municipal sewage treatment is not applicable to the control of feedlot pollution. Cattle feedlot runoff is a highly concentrated organic waste. The strength may equal that of normal domestic sewage or may be 10, 100, 1,000 or more times greater. Feedlot runoff may still contain, after treatment, as high pollutional parameters as domestic sewage, before treatment, if percent removal is the only criterion used for treatment. Therefore, a "residual" concept of waste treatment is proposed. That is, acceptable treatment is that which reduces the pollution to a prescribed level or residual which would assure adequate treatment.

Our laws must give due consideration to the location of feedlots. Feedlots have generally been located without regard to the soil inventory and associated topographical characteristics. It may be not only desirable, but also necessary, to employ zoning regulations to prevent not only the encroachment of the animal population into urban areas, but also prevent the encroachment of the human population into the feedlot areas. Hawaii and California have shown the way with the passage of land conservation acts. Basically, their legislation prevents encroachment of urban development into agricultural areas and also provides a more favorable tax assessment for agricultural lands.

Regulations should also provide for a continuing, comprehensive animal inventory, state by state, drainage bain by drainage basin, which would provide definitive data on the character and composition of agricultural effluents, points of discharge and other pertinent information. Just as we census the human population, we must also keep up to date inventories of animal populations.

Leadership in animal waste control is not limited to the official agencies. Research has been underway in the state agricultural experiment stations regarding the characterization, handling, and utilization of animal manures since the turn of the centruy. The U. S. Department of Agriculture and many other Federal and State agencies are conducting studies related to agricultural pollution.

CONCLUSION

An enlightened public has shown in all fields of environmental protection, including water pollution control, that it is willing to pay, in dollars, the added costs of maintaining a high quality environment, rather than risk its own destruction. Enlightened leadership will continue to create its own consensus. The program before you today is a step toward progressive leadership.

SUMMARY

This paper has presented an overview of the causes and effects of animal waste pollution on water quality. The extent of the problem as well as the effects on surface and ground waters are illustrated with research data. The present status of legislation in regulatory control of pollution is discussed. Measures to strengthen present regulations are proposed.

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ANIMAL WASTES -- A MAJOR POLLUTION PROBLEM

*By Richard R. Dague

In the past, wastes from humans and industries have been considered the major sources of water pollution. With increases in population, the migration of people from rural to urban areas, and increasing industrial development, these waste sources have become even more significant. Along with population growth and the shift from an essentially rural to an essentially urban society has come increasing demand for food and fiber. This demand has been satisfied by decreasing numbers of farm operators on fewer farms. This has led to the concentration of greater numbers of livestock on fewer farms. In recent years, it has been recognized that the concentration of large numbers of livestock in small areas for feeding represents a significant source of water pollution.

WATER POLLUTION POTENTIAL

The population equivalent (PE) of livestock on Iowa farms, based on the biochemical oxygen demand (BOD) of the animal wastes, is near 100 million. Iowa is the leading state in the U.S. in the production of swine and beef cattle and is among the leaders in the production of other meat animals. In 1966, Iowa farmers produced 24 per cent of the swine, 17 per cent of the beef cattle, 7 per cent of the turkeys, and 5 per cent of the sheep and lambs produced in the U.S.[1] The number of beef cattle marketed from Iowa feedlots each year is impressive. In 1967, this number was 4,057,000 compared to 3,066,000 from Nebraska, 2,049,000 from California, 1,654,000 from Texas and 1,321,000 from Kansas[2]. In Iowa the PE of the waste from beef cattle alone approaches 40,000,000, on a BOD basis.

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The human population of Iowa is 2.8 million. This number seems minute when compared with the PE values of farm animal wastes. One might ask: Why worry about water pollution from human sources ? It can be concluded that animal wastes do represent a significant problem in Iowa. But it does not follow that wastes from human sources can be ignored. First, the magnitude of the actual water pollution which can arise from farm animals is not as great as the PE numbers indicate. Animal wastes are different than human wastes, both in composition and the manner in which the wastes are commonly released into the environment.

Human wastes released to sewers are delivered to the treatment plant on a nearly continuous basis. In comparison, the transport of wastes from an animal feedlot to surface waters is intermittent. Wastes are transported from the lot only when rainfall and runoff occurs. Thus, of the total waste defecated by an animal on a feedlot a portion may be transported to surface waters in runoff. The remaining portion of the waste will remain on the feedlot surface as a manure accumulation. The volume, strength and rate of delivery of feedlot runoff to streams is a function of the topographic, meteorlogic, and hydraulic characteristics in the feedlot area. Factors such as the antecedent moisture conditions, temperature, nature of the lot surface, and animal density on the lot also affect the volume and characteristics of feedlot runoff[3].

The intermittent nature of the delivery of feedlot wastes to streams has both advantages and disadvantages. The advantage is the fact that all of the animal waste does not reach the stream. A large part of the waste accumulates on the feedlot surface and must be disposed of in the semi-solid form. The disadvantage is the fact that when rainfall and runoff occurs, wastes are washed to the stream on a slug basis. This tends to shock load the receiving stream, the extent of the shock depending on the strength and volume of the runoff and the nature of the receiving stream.

It is farm animals on open feedlots which are of major concern with regard to water pollution potential in Iowa. However, the feeding of animals in covered enclosures is being practiced. The extent of this practice, compared to feeding in the open, is limited at this time.

ANIMAL WASTE CHARACTERISTICS

The characteristics and quantities of the wastes released from animals varies considerably between different types of animals. This has resulted in considerable differences in numerical values for waste characteristics given in published reports. Several workers have presented data on animal waste characteristics[4,5]. Typical guide values are presented in Tables 1, 2 and 3 for cattle and swine, the two animals of principal concern in Iowa.

The data in Table 3 indicates that the organic material from bovine animals is much less subject to biological decomposition than human wastes. Typical domestic wastewater has a 5-day BOD to COD (chemical oxygen demand) ratio of about 0.5. Swine wastes are also less biodegradable than human wastes. From the data in Table 1, the BOD to COD ratio for swine is 0.27. In general, all animal wastes tend to exhibit the characteristic of being less biodegradable than a comparable quantity of organic material from humans. This is significant when considering biological processes as methods for treating animal wastes.

The data in Tables 1 and 2 indicate the potential pollution of the environment that might result from swine and cattle. However, the quantity of stream pollution from the wastes released from farm animals depends on occurrences after defecation of the wastes by animals. In many cases, farm animal wastes are deposited on feedlot surfaces. In order to cause water pollution, these wastes must be transported to the water.

ANIMAL WASTE REGULATIONS

Several states are establishing regulations for the control of animal wastes. Kansas was the first to regulate agricultural wastes. Iowa and Nebraska are in the process of establishing regulations, primarily for the control of wastes from cattle feeding operations.

Table 1. Characteristics of Swine and Cattle Wastes.
[From Taiganides and Hazen[4]]

Item	Units	Swine (100 lbs.)	Cattle (1000 lb.)
Wet Manure	lb./day	7.0	64.0
Total Solids	% Wet Basis	16.0	16.0
Volatile Solids	% Dry Basis	85.0	80.0
Nitrogen	% Dry Basis	4.5	3.7
Phosphorus (P_2O_5)	% Dry Basis	2.7	1.1
Potassium (K_2O)	% Dry Basis	4.3	3.0
BOD	[1] lb./day/100 lb.	0.34	0.13
COD	[1] lb./day/100 lb.	1.25	1.05

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[1] Values are per 100 lb. live weight.

Table 2. Quantities of Major Fertilizing Elements from Swine and Cattle Wastes.
[From Taiganides and Hazen[4]]

Item	Swine		Cattle	
	lb./day	lb./yr.	lb./day	lb./yr.
Nitrogen (N)	0.50	185	0.38	138
Phosphorus (P_2O_5)	0.26	110	0.11	41
Potassium (K_2O)	0.48	172	0.31	112

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[1] Values are based on 1000 lb. of live animal weight.

Table 3. Ratio of BOD to COD.
[From Witzel, et al.[5]]

Animal	BOD/COD
Dairy Bull	0.18
Dairy Cow	0.23
Beef Steer	0.31

The Kansas regulations became effective on March 1, 1967. These regulations require an operator of any feedlot containing 300 or more cattle, 100 or more swine, or 500 or more sheep to obtain a water pollution control permit from the State Department of Health. The regulations establish minimum waste control facilities required to obtain a permit. As a minimum, cattle feedlots must be provided with a retention pond capable of containing three inches of surface runoff from the feedlot area. Similar criteria apply to sheep feedlots. For swine, waste retention lagoons must be capable of retaining all animal excreta, litter, feed losses, wash waters and, in addition, be capable of retaining three inches of rainfall runoff from all contributing drainage areas. The regulations permit the use of other control systems if it is judged that effective results can be obtained by the alternate procedure. In addition, the rules permit the Health Department to waive the regulations for any feedlot operation which, due to location, topography, or other reasons, does not constitute a water pollution problem. From the standpoint of operation, the Kansas regulations permit the controlled release of liquid from retention ponds to streams in some areas. Waste solids must be spread on land surfaces and mixed with the soil in a manner which will prevent runoff of wastes.

In Iowa, regulations to control wastes from cattle feeding operations are in the process of being established. At this time (Dec. 1968) the Iowa Water

Pollution Control Commission has held public hearings at four locations in Iowa. The hearings were for the purpose of explaining and receiving public comment on tentative regulations and design standards proposed by the Commission. The regulations proposed require cattle feedlot operators to conform to certain standards governing the management of wastes. Since the regulations have not been completed, it is not possible to summarize the requirements for obtaining a permit.

In Nebraska, regulations to control cattle feedlot wastes are being prepared by the Water Pollution Control Council. At this time, the voluntary registration of feedlots is being used as a preliminary step in the development of regulations.

FUNDAMENTALS OF CONTROL

In Iowa, and other midwestern agricultural states, the major source of water pollution from livestock is open feedlots. Of principal concern are feedlots for swine, cattle, and sheep. In Iowa, potential pollution from other animal sources, such as poultry, are small in comparison. For these reasons, the discussion of control fundamentals will be limited to open feedlots.

Feedlot wastes arise from a single source, the animal, but two wastes with vastly different characteristics result. One is the manure accumulating on the lot. The other is the runoff from the lot. The fresh wastes defecated by swine and cattle contain a moisture content of about 84 per cent (Table 1). However, after a period of accumulating and drying on the feedlot surface the wastes may have a moisture content of 40 to 50 per cent or less[6]. The runoff from feedlots is a liquid. The quantity and strength of the runoff portion of the wastes depends on several factors. Among these factors are the climate of the region and the area and nature of the feedlot surface. The control of feedlot runoff is complicated by the fact that the volume and rate of delivery of the waste is extremely variable, even for a specific feedlot site. Delivery of the waste to a stream or treatment facility is intermittent occurring only as the result of runoff-producing stroms. Therefore, the hydrology of the area, including rainfall, runoff, and stream flow, is a major factor to be considered when selecting waste management techniques. The actual volume and rate of runoff is a function of the rate of rainfall, the area of the feedlot, and the infiltration capacity of the feedlot surface. In working with experimental cattle feedlots at Kansas State University, Miner et al. found that the infiltration capacity of an unsurfaced feedlot surface was very small, after an initial period of rainfall sufficient to satisfy antecedent moisture defecits[3]. Although data from other feedlots is lacking, one might expect runoff coefficients for feedlots to be high as a result of compaction of the feedlot surface by the animals.

From the standpoint of feedlot runoff, the animal stocking rate is an important factor. Animal densities in cattle feedlots are generally in the range of 100 to 200 head per acre. Thus, for two cattle feeders each with 1,000 head of cattle but one providing one acre per 100 head and the other providing one acre per 200 head, the volume of liquid waste from the former feedlot would be about twice as great as from the latter, all other variables being equal. This results from the fact that the area of the first feedlot would be twice the area of the second.

Disposal of feedlot manure accumulations is a major problem, particularly for a large cattle feedlot. The dry weight of the total solids defecated each day from a 1,000 lb. beef animal is about 10 lb. (Table 1). For a feedlot containing 1,000 head of cattle, daily solids production would be 10,000 lb. with about 8,000 lb. being volatile solids. The nitrogen content of the waste solids is about four per cent (Table 2). Thus, daily nitrogen production would be about 400 lb. Phosphorus production would be about 100 lb., as P_2O_5 (Table 2). The problem is to merge this quantity of wastes into the environment without creating undesirable conditions -- and at a tolerable cost to the cattle feeder.

There are few feasible alternatives available for the disposal of feedlot manure wastes. The biological treatment of solids from cattle feedlots has been proposed[6]. However, even with a completely mixed anaerobic system operating at a temperature of 35°C, the reduction in total solids will amount to only about 50 per cent[6]. For 1,000 head of cattle, about 5,000 lb./day (dry weight) of solids would remain for ultimate disposal. Another significant factor is the moisture content of the manure. Fresh manure defecated from cattle has a moisture content of about 84 per cent but with proper timing of feedlot cleaning operations, the manure accumulations may have a moisture content as low as 40 to 50 per cent. This means a weight reduction of nearly 50 per cent by taking advantage of natural drying. In comparison to the use of an anaerobic lagoon to achieve a reduction in solids, the direct disposal of feedlot manure accumulations to the land appears best.

The disposal of feedlot manure to the land is not without problems. Ideally, it would seem best to utilize the manure on crop lands to obtain the benefit of the fertilizer elements in the waste. However, the recovery of nutrients by growing crops requires large areas of land. For example, 1000 head of cattle will defecate about 80,000 lb. of nitrogen (as N) in a 200-day feeding period. Even with a nitrogen application of 200 lb/acre on crop land, an area of 400 acres would be required. This calculation assumes that all nitrogen defecated by the beef animal is recovered and is available as a crop nutrient. Neither of these assumptions is entirely correct. Some nitrogen will be lost from the feedlot manure accumulation as a result of runoff. Some loss of ammonia to the atmosphere will occur, but this loss should be small at the pH of 7 to 8 common in feedlot manure accumulations. However, even if allowances are made for possible losses of nitrogen in runoff and to the atmosphere, it can be seen that a large area of land would be required for the disposal of manure from 1,000 cattle, if the aim is the recovery of nitrogen in crops. A complicating factor in efforts to apply manure to crop land is the intermittent availability of land to receive manure coupled with the continuous production of manure by the animals. If manure is to be applied to crop land, stockpiling of the manure during periods of the year when land is not available, due to standing crops or other reasons, will be required.

Another alternative for the disposal of feedlot manure is application to the land for the sole purpose of manure disposal, without regard to nutrient recovery. In this case, the manure may be applied heavily to the land. The danger in this practice is the potential pollution of ground and surface waters resulting from the heavy concentration of organic matter and fertilizer elements in a small area. When this practice is adopted, the area for manure disposal must be selected carefully. The practices employed in site selection and subsequent management are not unlike those applied to sanitary land fills used for municipal refuse disposal. However, the potential for environmental pollution resulting from cattle manure is even greater than from municipal refuse. This is particularly true with respect to pollution of ground waters with soluble forms of nitrogen. This problem can be minimized by proper site selection followed by proper operation. An ideal site would be one where surface runoff from surrounding areas does not flow across the disposal area; where underlying soils are tight, to minimize the percolation of water through the deposited manure and into the ground water; where pollution of deep aquifers is impossible, due to an aquiclude, and where the possible loss of some nitrogen to a shallow aquifer will be of small consequence; where the area is relatively isolated from human habitation, to reduce potential esthetic problems; and where sufficient soil is available for use as a cover material for the deposited manure. The considerations in the previous list are presented as goals and not as requirements that must be met in every case. As with all industrial wastes, each feedlot manure disposal problem must be analyzed separately and a method of disposal selected on the basis of considerations of public health, esthetics, and economics.

Management of the liquid portion of the wastes from feedlots, the surface runoff, poses a problem quite different from the disposal of the solid portion (manure). The liquid waste arises as a result of precipitation followed by surface runoff. Therefore, the quantity of waste from this source is tied to the hydrology of the area. As with other industrial wastes, the first consideration should be reduction of waste releases at their source. For 1,000 head of cattle, a feedlot area of from 5 to 10 acres is likely. For purposes of discussion, an annual precipitation of 36 inches might be assumed for Iowa. Assuming a minimal loss as a result of evaporation and infiltration, a runoff totaling 24 inches could result. For these assumptions, the annual waste volume for the 5 and 10 acre feedlots, both containing 1,000 head of cattle, would be 10 and 20 acre-feet, respectively. From the standpoint of potential stream pollution from runoff, it is important that animal densities on feedlots be as high as feasible. A higher animal density results in a more rapid manure accumulation on the lot, per unit of area, but this does not result in a proportionate increase in the strength of the runoff. Starting with a clean feedlot surface, Miner et al. found that the strength of runoff from feedlots having a cattle density of 200/acre reached a maximum after about two weeks of manure accumulation on the lot[3]. This indicates that increasing animal densities on the feedlot is an effective method for reducing the volume of liquid waste arising from a given number of cattle. Obviously, there is a practical limit to the amount the animals can be concentrated on the feedlot without impairing the welfare of the animals. Information on these density limits must be obtained from workers in animal husbandry and related areas.

A number of other factors affect the nature of feedlot runoff. Miner et al. found that the quantity and strength of runoff from experimental cattle feedlots was a function of temperature, rainfall rate, and the moisture content of the manure accumulated on the lot[3]. There is little that can be done to control these variables. However, these workers also found that the nature of the feedlot surface had a significant effect on the pollutional strength of the runoff. Runoff from a concrete-surfaced lot was more heavily polluted than runoff from a nonsurfaced lot, all other conditions being the same[3]. Based on suspended solids, losses from a concrete-surfaced lot ranged from 1,100 mg/l to 13,500 mg/l. From nonsurfaced lots the range in suspended solids was from

1, 100 to 7, 000 mg/l. In addition, the suspended solids from the concrete lot were 75 per cent volatile compared to 39 per cent for the dirt lot[3]. Therefore, from the standpoint of stream pollution, nonsurfaced feedlots are preferable.

Another factor to be considered in controlling feedlot runoff is the topography of the area. Runoff from areas outside the feedlot should not be allowed to flow into the feedlot. Also, feedlot slopes should not be excessively steep. Steep slopes favor the scour of manure from the feedlot surface. The requirement of flat slopes, to minimize the transport of solids from the feedlot, is at odds with the cattle feeders desire for a well-drained area. The goal should be a feedlot surface as flat as possible, but not so flat as to create problems with ponded water.

Once everything possible has been done to minimize the quantity and strength of the runoff waste, as suggested above, the next step is the management of the liquid waste which remains. There are four basic procedures that might be followed. These are: 1) uncontrolled release of the runoff to a stream, 2) controlled release to a stream following a period of retention in a pond, 3) release to the land after a period of retention in a pond, and 4) biological treatment followed by release to the land or to the stream. The actual method employed for a given feedlot should be selected on the basis of the degree of treatment required for the receiving waters. However, a few general guidelines can be presented.

Uncontrolled release of the feedlot runoff to the stream is not always the least desirable alternative. Runoff from feedlots occurs during periods of rainfall. Likewise, runoff from adjacent areas occurs during rainfall. The amount of dilution of the feedlot runoff which can occur during a runoff-producing storm depends on the relationship between stream flow and flow from the feedlot. For example, the five-acre feedlot, previously used as an example, would require a runoff of equal depth from an area of 500 acres to accomplish dilution of the feedlot runoff by a factor of 100. Miner et al. found BOD ranges from 220 to 1, 000 mg/l in the runoff from experimental cattle feedlots[3].

Assuming the highest value for discussion purposes, a dilution factor of 100 would reduce the concentration of BOD to 10 mg/l. Dilution factors will often be much higher than 100, further reducing the effects of feedlot runoff on receiving streams. The decision regarding the use of some form of feedlot runoff control or treatment facility should be made only after it is shown that uncontrolled release of the runoff will impair the water quality for some legitimate downstream water use.

The use of a runoff-retention pond, followed by controlled release to the stream, is another possible control procedure. The collection of feedlot runoff in a retention pond will result in a reduction in the suspended solids and BOD of the runoff as a result of plain settling. The writer observed COD reductions ranging from 25 to 40 per cent as a result of solids removal from cattle feedlot runoff by plain settling for time periods ranging from 2 to 24 hours. Plain settling can result in a significant decrease in the strength of cattle feedlot runoff. However, the solids removed by plain settling must be disposed of in some way. The fixed fraction of these solids may be quite high, perhaps 60 per cent. Therefore, the benefit in solids reduction which may be accomplished by anaerobic digestion of the solids is low. Even with a 50 per cent reduction in volatile solids, 80 per cent of the original total solids would remain for ultimate disposal. Therefore, a significant reduction in solids as a result of biological activity in retention ponds should not be expected. The solids collected from feedlot runoff should be disposed of along with the feedlot manure accumulations.

A danger in the use of retention ponds for the collection of feedlot runoff is the rapid filling of the pond with solids. In Kansas, some ponds designed to hold three inches of runoff became full of solids within three years after construction. A pond full of manure solids is more costly to clean than the original cost of pond excavation. It is essential that the retention ponds be protected from filling with solids or be shaped so that they can be easily cleaned. One cattle feedlot (30,000 head capacity) in Kansas makes use of long, flat-sloped ditches to transport the runoff to retention ponds. These ditches are effective in allowing solids to settle prior to discharge of the runoff into the retention ponds. The accumulated solids are then cleaned from the outlet ditches at intervals.

After settleable solids are removed from feedlot runoff, the problem of disposal of the liquid remains. One alternative is the controlled release of the liquid waste to the stream. A second possibility is spreading the liquid on land. A third choice is the further stabilization of the waste by biological treatment followed by release of the effluent to the stream.

The simplest method for disposing of the pre-settled liquid runoff is controlled release to the stream. In many cases, this practice will provide the necessary degree of waste control. Plain settling will prevent the release of large quantities of settleable solids to the stream. The gradual release of the liquid will prevent shock loading of the stream. Thus, this relatively simple runoff control practice can accomplish a great deal in preventing stream pollution.

The discharge of accumulated feedlot runoff to the land is a possible method for disposal of pre-settled feedlot runoff. However, unless a large retention pond is used to collect runoff, the method may not be a significant improvement over controlled release to the stream. A pond having a volume equal to two inches of feedlot runoff has been suggested for application to Iowa feedlots. With a storage volume of only two inches, it is certain that direct releases to the stream will occur frequently during periods of short rainfall recurrence interval. These periods tend to occur during the spring when the land areas which are to receive the feedlot runoff are likely to be wet and in the worst condition to receive further liquid. In selecting a volume for a retention pond to act as a buffer between feedlot runoff and subsequent waste releases to land, careful consideration must be given to hydrologic factors, including rainfall intensities, durations, and recurrence intervals. Once this is done it will be possible to establish the probability of any runoff accumulation being experienced during any given critical period.

Another alternative for possible application to the management of the liquid portion of feedlot runoff is biological treatment. One author has proposed a biological treatment system involving an anaerobic lagoon, aerated lagoon, and an oxidation pond in series[6]. Ponds can be operated in a manner to equalize surge flows which occur during runoff. A high degree of waste stabilization is possible. The problem with this technique is the large amount of land required and costs, both first costs and operational costs. Although biological treatment will accomplish the stabilization of pre-settled feedlot runoff, it appears best to avoid this method if possible.

TREND IN FEEDLOT OPERATIONS

The trend to meat consumption in the U.S. is upward. The consumption of beef has increased at a rate of 3.6 lb. per person per year for the last seven years[6]. Based on 1964, when the per capita annual consumption of beef was 100 lb. per year, the rate of increase has been over three per cent per year. Although increases in consumption of other meats, such as pork and mutton, have been moderate compared to beef, the overall trend in meat consumption in the U.S. is upward.

Increased demand for meat has resulted in increased production. Also, the larger quantity of meat is being produced by decreasing numbers of farmers. Thus, feeding operations are getting fewer in number and larger in individual size. This trend increases the potential for environmental pollution. In the future, feeding facilities must be designed and operated not only to optimize meat production but also to minimize pollution.

Regulatory Aspects of Feedlot Waste Management

by

Melville W. Gray, P.E.*

Traditionally, animal wastes have been considered a part of the general agricultural community, and little or nothing has been done to control these wastes from the standpoint of water pollution. Considerable effort has been expended over the past years in the control of silt through the general principles of conservation; however, it has not been until recent years that silt and animal wastes in general were considered as specific water pollutants.

The Department of Health first became concerned with feedlot operations in about 1956. The concern was brought about by people living in the immediate area of feedlots who complained of nuisances due to odor and fly production. Departmental concern was shifted to water quality control in 1959, when fish kills began occurring downstream from the very few feedlots existing in the state at that time. Interest in the animal feedlot industry by the department of health resulted in the conclusion that feedlots could become a significant water pollution problem with continued growth, so that detailed investigations of pollution characteristics and growth patterns were undertaken in conjunction with research investigations at Kansas State University and the University of Kansas.

While at the present time major emphasis for control of animal wastes from the water quality standpoint is directed toward the commercial cattle feedlot, it should be understood that with increased population, industrialization, and an expanding economy in general, these factors contribute to the overall problem created by increased numbers of livestock in the state. As an example, during the period from 1940 to 1968, the total number of cattle in Kansas grew from 2.75 million to approximately 6 million head. In 1956 there were only 30,000 head of cattle in commercial feedlots, whereas on 1 October 1968 there were in excess of 400,000 head of cattle in commercial feedlots. A commercial feedlot is defined as having 1,000 or more head of cattle. Each of the 6 million head of cattle in the state contributes to the degradation of our environment. Due to the large concentration in terms of numbers of cattle in commercial feedlots, there is a significant point source pollution potential which has the capability of upsetting the balance of our environment and must be controlled.

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Environmental Significance of Feedlots Wastes

Animal wastes in general and feedlot wastes in particular, because of their concentration, significantly influence the environment in four principal areas as follows: (1) fish and other aquatic life; (2) sources of water supply, both surface and ground water; (3) body contact recreation areas in surface water, and (4) creation of nuisances which offend the esthetic realm.

Fish kills are dramatic and provide easy-to-compare numbers for purposes of cause and effect. It is of interest to note that the Federal Water Pollution Control Administration, which is responsible for the reporting of pollution-caused fish kills throughout the United States, indicates that in 1967 pollution-caused fish kills by agricultural wastes replaced municipalities and industry as the number one cause of fish kills in the United States during the calendar year. Kansas contributed greatly to this number one causative agent during

1967 by recording almost 10% of the total numbers of fish killed in the United States and this was due to agricultural waste pollution. In the calendar years 1963 through 1967, there were 84 significant fish kills as reported by the Kansas Forestry, Fish and Game Commission. Of these 84 significant fish kills, 65% were caused by animal wastes. During the same period of time the percentage of numbers of fishes killed directly attributable to animal wastes ranged from a low of 82% to a high of 99%. The principal cause of fish death as the result of animal wastes in receiving streams is depression of the oxygen content of the water below that which will sustain life, and in most instances investigated by the department of health, the oxygen content of the receiving stream has been 0.0 milligrams per liter. There are some instances where the ammonia content in the receiving stream, as the result of animal waste runoff, is sufficient to strip the mucous membrane covering from the fish body and allow extreme irritation of the flesh so that hemorrhaging occurs. Under these circumstances the gills of the fish are also extremely irritated, hemorrhaging occurs, and death results.

The writer has observed plug flow of animal wastes in the receiving stream over a distance of several miles where fish were surfacing, trying to obtain oxygen from the air, and crayfish were alternately crawling up the bank out of the water and back into the water again. The flow in the stream at the time was estimated at 500 cfs. The BOD_5 was 105 mg/l, dissolved oxygen 0.0 mg/l, and the ammonia content 7.0 mg/l as nitrogen.

Surface water supplies in Kansas can be seriously disrupted for a period of from one day to two weeks by a single incident of feedlot waste runoff. In 1967 one small Kansas community using surface water as a supply source was forced for a period of two weeks to treat water with the following characteristics: ammonia content up to 20 mg/l; BOD_5 up to 75 mg/l; dissolved oxygen 0.0 mg/l; total coliform count 4 million; fecal coliform count 2 million, and total fecal streptococcus count at 5 million per 100 m/l sample. Additionally the water was heavily loaded with pungent and difficult-to-describe organic materials which produced a finished water product highly offensive to the senses of taste and smell. The city was forced to use activated carbon and increase chlorination by a factor of 10 in order to not-too-successfully continue operation of the water treatment plant.

Kansas contains sufficient surface water reservoirs to allow considerable body contact recreation in the form of swimming, water skiing, etcetera. Over the past few years, the economic value to the state associated with recreational boating is estimated to be $40-$50 million per year. In June of 1967 considerable quantities of animal waste runoff reached the main body of John Redmond reservoir. The Kansas State Department of Health has established a bacteriological quality objective of less than 1000 coliform per 100 ml sample for body contact recreation areas. Upon reaching John Redmond reservoir, the animal waste runoff produced total coliform counts per 100 ml sample of from 1000 to 100,000 bacteria throughout the reservoir area. There are probably in excess of 200 diseases capable of being transmitted from domestic animal to man, and in excess of 50 diseases which can be transmitted to man from animal via water. As a result of this pollution it was necessary for the department of health to notify the general public that John Redmond reservoir was unsafe for body contact recreation until further notice. The unsatisfactory bacteriological conditions existed within the reservoir for a period of approximately two weeks before the department of health was able to advise the public that it was again safe for body contact recreation.

Esthetics and nuisance factors as related to animal feedlot wastes are principally involved with odors as a result of continuous quantities of manure and feed products, and fly production and high rodent population as a result of availability of manure and waste feed products. These factors can become serious to the immediate community if a dynamic insect and rodent control program and adequate sanitation measures are not implemented.

Field Investigations and Waste Characteristics

Because of the sheer numbers involved, the cattle feedlot animal waste problem is the most severe in Kansas. Waste deposited within the feeding pens having a density of 200-300 head of cattle per acre becomes intimately mixed with the topsoil, and in dry weather becomes firmly packed. The most extreme conditions of water pollution from the feedlot surface occur when a light rainfall of approximately one-half inch is followed one or two days later by one and one-half to two inches of rainfall where considerable surface runoff occurs. After the initial one-half inch rainfall, the hoof activity of the animals will produce a semi-liquid state of the manure and urine laden topsoil so that considerable amounts of material are readily dissolved, suspended and carried off in the succeeding runoff. During this period of runoff, the water pollutants may be several times the population equivalent of the animals within the feedlot. Runoff under these conditions is characterized by extremely high bacterial counts, high BOD_5, and significant concentrations of ammonia in solution.

The quantity of waste derived from domesticated animals is significant in the numbers with which we are involved today. These wastes can be equated in terms of population equivalent as follows:

	Population Equivalents	Wet Weight of Wastes
Sheep	1-2	4-5 lbs
Hogs	3-4	15-25 lbs
Cattle	8-10	40-60 lbs
Dairy Cattle	7-9	60-80 lbs

The wet weights in the tabulated data include both feces and urine and in the case of cattle, the urine amounts to 15-20 lbs. per day. These population equivalents and wet weights of the wastes are rule-of-thumb figures used by the department of health with the recognition that they are variable figures, being functions of individual animal weight and diet, and do not represent a daily waste discharge to waters of the state. A surface water pollution potential as the result of runoff is highly variable and dependent upon rainfall frequency, rainfall intensity, land surface topography, lot surface or soil type, and lot sanitation procedures.

Since 1960, the Kansas State Department of Health has investigated in excess of 150 fish kills which were the direct result of animal wastes. The details of these are attached as an appendix to this paper. These investigations have ranged from the very cursory and obvious by determination of source of pollution and the ascertaining of the depressed oxygen content within the stream, to the very complete investigations as conducted by Smith and Miner in 1963. Examples of two relatively thorough fish kill investigations are attached as part of the appendix.

Investigations conducted by the department result principally due to a report of local citizenry or officials from the Kansas Forestry, Fish and Game Commission. Notification may be obtained by the department within a period of time ranging from a few hours after the fish kill commences to as late as seven to ten days after the kill. In most cases of investigation, the maximum runoff directly from the feedlot surface has already occurred at the time of sampling. The maximum BOD_5 and ammonia content of direct runoff from feedlot areas the department has measured are 8000 mg/l and 285 mg/l respectively. Maximum observed pollutant characteristics for a river of substantial flow were obtained at an estimated 500 cfs flow from the Cottonwood River as follows: BOD_5, 105 mg/l; ammonia 7.0 mg/l; total coliform, 12.0×10^6 per 100 ml; fecal coliform, 9.1×10^6 per 100 ml, and fecal streptococcus, 41.0×10^6 per 100 ml sample. Maximum observed characteristics for effluent from feedlot retention ponds designed for a retention capacity of two to three inches of surface runoff are as follows:

	Primary Cell	Secondary Cell
BOD_5	2800 mg/l	5500 mg/l
NH_3 as N	232 "	400 "

It can be said with certainty that pollution characteristics of feedlot runoff and runoff retained in retention ponds will vary considerably from time to time dependent upon frequency, intensity and distribution of rainfall, physical characteristics of the feedlot area, and the result on the receiving stream will be affected by the same variables in addition to water temperature.

Applicable Law and Regulation Requirements

Kansas statutes applicable for the purposes of this discussion governing water pollution control from municipalities and industries (including feedlots) are contained in KSA 65-161 through 65-171h as revised in 1967. Within these statutes, the authority and definitions are set forth enabling the Kansas State Department of Health to prohibit and otherwise control water pollutants. A brief review of these statutes follows:

The term "waters of the state" shall include all streams and springs, and all bodies of surface and of impounded ground water, whether natural or artificial, within the boundaries of the state.

Sewage is defined as any substance that contains any of the waste products or excrementitious or other discharges from the bodies of human beings or animals, or chemical or other wastes from domestic, manufacturing, or other forms of industry.

Pollution is defined as such contamination, or other alteration of the physical, chemical, or biological properties of any waters of the state as will or is likely to create a nuisance, or render such waters harmful, detrimental, or injurious to public health, safety or welfare, or to the plant, animal, or aquatic life of the state, or to other legitimate beneficial uses.

State law provides that to enable the discharge of any sewage to waters of the state, a permit must be obtained from the State Board of Health. If the issuance of a permit is deemed to be in the best interests of the state, the Board of Health shall stipulate in the permit the conditions on which such discharge will be permitted and shall require such treatment of the sewage as is determined necessary to protect beneficial uses of the waters of the state. Permits for discharge of sewage are revocable on due notice. The length of time after receipt of a notice within which discharge of the sewage shall be discontinued may be stated in the permit, but in no case shall it be less than 30 days or exceed two years, and if the length of time is not specified in the permit it shall be 30 days. On the expiration of the period of time described, after service of notice of revocation, modification or change from the State Board of Health, the right to discharge sewage into any waters of the state shall cease and terminate, and the prohibition of the act against such discharge shall be in full force, as though no permit had been granted.

Upon making application for a permit to discharge sewage into waters of the state, the application shall be accompanied by plans and specifications for the construction of the sewage collection systems and/or sewage treatment or disposal facilities, and any additional facts or information as the state board of health may require to determine adequate protection of the public health of the state and the beneficial uses of waters of the state.

The Kansas State Board of Health is empowered to adopt rules and regulations including registration of potential sources of pollution, for the purpose of preventing surface and subsurface water pollution and soil pollution detrimental to public health or to the plant, animal and aquatic life of the state, and to protect beneficial uses of the waters of the state. In making rules and regulations, the state board of health, taking into account the varying conditions that are probable for each source of sewage and its possible place of disposal, discharge, or escape, may provide for varying the control measures required in each case to those it finds to be necessary to prevent pollution and protect the beneficial uses of the waters of the state.

Failure to comply with the rules, regulations and orders of the state board of health is deemed to be a misdemeanor and upon conviction shall be punished by a fine of not less than $25 and not more than $250. The failure to comply with such requirements and orders in each day in which failure is made, shall be considered to constitute a separate offense.

The penalty for discharge of sewage into waters of the state without a duly issued permit is $1000 and a further penalty of $1000 per day for each day the offense is maintained. Penalty for failure to comply with requirements of the state board is a fine of not less than $50 and not more than $500, and failure to fully comply with requirements of the board is $25 and not more than $100 for each offense, with each day in which such failure is made considered as a separate offense.

Regulations for Agricultural and Related Wastes Control

Regulations for agricultural and related wastes control are contained in Kansas State Board of Health regulations 28-18-1 through 28-18-4. These regulations were adopted as emergency regulations, as provided for in state statutes, in mid-1967 and were re-adopted as permanent regulations effective 1 January 1968. It is the intent of these regulations to control water pollution from the confined feeding of animals and they are applicable to (1) the confined feeding of 300 or more cattle, swine, sheep or horses at any one time, or (2) any animal feeding operation of less than 300 head using a lagoon or (3) any other animal feeding operation having a water pollution potential, or (4) any other animal feeding operation whose operator elects to come under these regulations. Effective 1 July 1967, the operator of any newly proposed confined feeding operation was required to register with the Kansas State Department of Health prior to construction and operation of the lot, or construction of the waste control facilities. The operator of an existing confined feeding operation was required to register by 1 January 1968; however, due to apparent misunderstanding among feedlot operators, the Board of Health extended this registration date to 1 April 1968. A water pollution control permit is required when water pollution control facilities are necessary. The permit will not be issued until satisfactory completion of construction in accordance with plans and specifications approved by the department of health. The water pollution control permit is revocable for cause on 30 days' written notice. Upon revocation of the water pollution control permit, the owner of a confined feeding operation is allowed to finish feeding the existing animals at the time of revocation, but is not allowed to bring any additional animals in to the feeding operation until requirements for water pollution control have been met, and a new water pollution control facilities permit has been issued.

The implementation of these regulations are rather unusual in that they provide for considerable flexibility for departmental engineers in that greater or lesser requirements may be imposed based on engineering judgment, and the specifics of each individual case. Average rainfall in Kansas varies from 16 inches per annum in the far west to 40 inches per annum in the east, and with these highly varying conditions it becomes apparent that each individual installation must be evaluated on its own merits if we are to realize satisfactory water quality control at reasonable cost. We do have extensive rainfall records at numerous locations throughout the state, and have developed factors for the design of animal waste water pollution control facilities which we feel will be adequate. Within the central portion of the state, two-day rainfall probabilities are five inches and eight inches for 10-year and 100-year probabilities respectively, while a ten-day rainfall of seven inches and 11 inches can be anticipated for 10-year and 100-year probability of occurrence respectively. The probable maximum six-hour rainfall for 10 square miles is 26 inches. It becomes obvious we cannot be expected to provide water quality control retention structures for the maximum probable rainfall occurrence, nor are they needed. Additionally, due to the highly varied rainfall occurrence between the western and the eastern portions of the state, it is not logical to impose uniform requirements statewide.

The basic premise for water pollution control facilities with respect to feedlots has been based on the following factors:

1. The characteristics of wastes associated with runoff from feedlot areas

are independent of the population equivalent of the feedlot.

2. Dry-cleaning - that is mechanical removal of the deposited wastes within the feedlots-is impracticable in that it is not feasible to dry clean the lot except during periods of feedlot pen turnover, which in the case of cattle occurs between 90 and 120 days. Research has further shown that unless dry-cleaning of the cattle feedlot surface can be provided at intervals more frequent than two weeks, pollution characteristics of surface runoff remain unchanged.
3. Because of the extreme organic content of the wastes, both on a daily basis and surface runoff, it is technically impracticable and economically impossible to treat the wastes from cattle feedlots so that they can be discharged to the environment with immunity.
4. Waste water evaporation ponds for large area installations are infeasible because of the large areas required in all except the western portion of the state, where rainfall is minimal and evaporation may exceed 80 inches per year. Even so, the area required for evaporation approaches the area of the feedlot if there is to be no overflow at any time.

It is the intent of the department to provide the necessary water pollution control at minimum expense to the owner, while at the same time maintaining the objectives and requirements of water quality.

Cattle Feedlot Facilities

Under the philosophy that it is not economically practicable to treat the surface runoff from cattle feedlot areas, or even if it was determined that treatment was desirable, it behooves us to exercise control only over that portion of surface runoff which becomes polluted from the waste materials involved. It is recommended that the owner divert all extraneous surface flows around the cattle feeding area so that it can flow to the normal drainage course unaffected by the waste material. If the operator does not choose to divert extraneous flows he must make allowance in retention or treatment facilities for this additional flow. It is the current policy to assume that under normal conditions of rainfall occurrence and intensity, the owner can successfully maintain water quality control by the provision of retention ponds with a capacity to retain three inches of surface runoff from the contributing drainage area. Dewatering facilities (usually in the form of an irrigation system) must be provided, with the capability of emptying the retention structures to a satisfactory disposal site within a period of five days. It is present policy that the retention ponds must be emptied within a period of ten days after rainfall. This will allow for a minimal period of time for surrounding land surface areas to partially dry before application of the liquid wastes. In most instances, two or more retention ponds operated in series are required. Because of the nature of the runoff water and waste materials consisting of large quantities of silt, manure and grain, this "shud" will settle out rather rapidly in a primary cell. The primary cell can be sized to accommodate more readily available means, that is draglines or pumps, in removing the shud from this small cell than could be done in one large retention pond.

The solid waste materials removed from the surface of the feedlot pens and solids removed from retention ponds must be disposed of in a manner which will not contribute to water pollution, both ground and surface waters. The

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conventional method for disposal of these materials is to spread them on agricultural land and turn them under as soon as possible. Land application rates of these materials are highly varied and at the present time range from as little as five tons per acre per year to as much as 300 tons per acre per year. Land application of the solid wastes can be complicated by the seasonal status of crops and the moisture content of the fields. It is therefore usually necessary to stockpile the solid wastes until conditions will permit application to the field. The stockpiling of these materials should be conducted in a location not subject to contact from significant surface runoff, and in some instances diking is necessary around the stockpiled material to prevent runoff or leaching into surface water streams.

Swine Feedlot Facilities

There is normally greater variance in the quantities of waste materials and liquids in swine feeding operations than is the case with cattle feedlot operations. Some swine feeding operations are conducted in the manner of the cattle feedlot operations with open dirt surfaced pens, and in this instance the approach is identical with that of the cattle feedlot waste control requirements. Many swine feeding operations are completely enclosed so that rainfall and surface runoff are not involved. In this event, waste material storage can be provided for the convenience of the operator dependent upon the frequency with which he desires to haul or otherwise remove waste materials to agricultural land for ultimate disposal. Where surface runoff and rainfall is not a consideration, 30 cubic feet of storage capacity per head is considered adequate with removal of waste from the retention facility no more than one time per year. In some instances, cooling water sprays will be utilized by the operator during periods of hot weather. In this case, volumetric considerations must be made for the cooling water and allowances made in the retention facilities.

Slotted floor operations or those where all materials are scraped into receiving pits are suitable for the application of racetrack lagoons. These systems as currently employed on the market cannot be considered satisfactory treatment for effluent to be discharged to receiving streams. They will reduce the strength of wastes by 90% or more; however, effluent characteristics can still be considered to have a BOD of 500 to 1000 mg/l and effluent from the racetrack lagoon must be contained within a holding lagoon or holding basin for ultimate disposal to agricultural land. The ractrack lagoon application will sometimes approach balance from a liquid standpoint with little or no effluent discharge due to evaporative losses. It can maintain enclosed hog-feeding houses in a relatively odor-free condition.

In all but very unusual instances, true waste treatment facilities by means of anaerobic and/or aerobic lagoons are not feasible because the water balance dictates that complete retention can be attained with lesser volume requirement than would be the case for aerobic treatment with effluent discharge. Where treatment rather than retention is considered feasible, an average value for strength and volume of waste per hog is 0.3 lbs of BOD_5 per day, and 0.3 cubic feet per day respectively.

Sheep Waste Control Facilities

Water pollution control facilities consisting of waste retention ponds for runoff from sheep feeding operations are designed on a basis identical to that of cattle feedlot operations. In the event a sheep feeding operation were completely enclosed similar to that in the swine feeding operations, the population equivalents would be one to two persons per day, the wet weight of wastes four to five pounds per day, and a volumetric waste factor of 0.07 ft^3 per animal per day.

Summary of Animal Waste Regulations

All existing animal feedlot operations having 300 or more head of animals at any one time, or any animal feeding operation utilizing a lagoon, must be registered with the Kansas State Department of Health. Any newly proposed animal feeding operation having 300 or more head of animals or one which proposes to use a lagoon must register with the department of health prior to operation of the feedlot, and obtain approval for waste control facilities prior to construction and operation. Department of health engineers will visit an existing or proposed feedlot site and advise the owner regarding required water pollution control facilities. Department of health engineers have the authority to exercise professional judgment regarding the degree of water pollution control required. In several instances, due to the location, topography and other influencing factors, it has been determined that water pollution control facilities are not required for the present time. Due to unusual conditions involved within a specific location or one in which downstream water quality requirements are critical, the department of health may require treatment and/or retention to the extent that is necessary to protect the area concerned. The requirements for water quality control as it relates to feedlot operations may be increased at any time it becomes evident that existing facilities are not providing adequate protection for the beneficial use of waters of the state. Conscientious operation and maintenance of the water pollution control facilities is essential, particularly in the dewatering of retention ponds as soon as possible after rainfall. Requirements for additional water quality control facilities or revocation of a permit can be anticipated if satisfactory operation is not provided.

The Kansas Livestock Sanitary Commissioner has the authority and jurisdiction over the sanitary conditions within the animal feedlot area for commercial feedlots. The Commissioner requires that all feedlot surfaces be adequately drained to prevent insanitary nuisance conditions, that concrete or other impervious material be placed around feed bunkers to facilitate cleaning, and prevent insect production, and that a satisfactory overall program of insect and rodent control be implemented within the feedlot. At least quarterly inspections are performed by personnel from the Livestock Sanitary Commissioner's office on all commercial feedlots.

Future Emphasis and Program Objectives

New or revised regulations for water quality control relative to animal feedlots are not anticipated in the foreseeable future. Additional emphasis will be placed on operation of the control facilities. The importance of operation in dewatering waste retention lagoons to agricultural fields cannot be overemphasized if we are to obtain our objectives.

There is the additional problem of protecting fresh ground water supplies. The application rate of manure from feedlots must be intelligently determined to balance crop uptake of waste materials applied. An application rate of 300 tons per acre of solid waste derived from dry-cleaning a feedlot surface will greatly exceed the nitrogen uptake of any crop produced, and as a result the excess nitrogen will become dissolved as nitrates into rainfall or irrigation water and percolate to the ground water table. There the nitrate becomes a threat not only to human consumers of ground water as a cause of methemoglobinemia, but also poses a threat to the stockman by causing cattle abortion and reducing weight gain in animals. It becomes apparent that in the overall control of these wastes by methods currently considered feasible, we must be cognizant of the capability of the complete cycle: that is, soil application rates and crop production requirements.

The necessity for feedlot operations having 300 or more animals at any one time to comply with existing regulations is administrative rather than factual, and the number of animals is highly arbitrary. This does not allow animal wastes from an installation having fewer than 300 head to be discharged to the environment with immunity. At any time water pollution is evident, the state department of health, under authority of the state statutes previously discussed, can issue a direct order requiring water pollution control facilities for any animal feeding operation regardless of size and number of animals involved. This would be appropriate in any instance and for any cause resulting in water pollution.

At the present time, the Kansas State Department of Health is operating a semiformal control program as it relates to dairy farm wastes. By reason of federal and state regulations for Grade A dairy farm operations, the operator of the dairy farm must provide satisfactory disposal of his household waste so that these materials will not provide a breeding source for flies and other insects which would be detrimental to the sanitary conditions within the milking parlor. The sanitary requirements within the dairy farm milking parlor dictate that the area must be cleaned and washed down regularly. It is common practice for waste materials involved with this cleaning operation to be discharged to the surface of the ground or to the nearest drainage ditch. Volumes of this waste material may vary from as little as two to three gallons up to 15 gallons per dairy cow milked, and will have a BOD_5 of 1000 to 2000 mg/l. It is possible to provide a satisfactory lagoon system which will accommodate the residential household wastes at the dairy farm and in addition, wastes generated in the cleaning of the milking parlor, at a lesser cost than would be required for installation of a septic tank-tile field which would take care of the domestic wastes only. The accepted method of treatment is to provide an anaerobic lagoon followed by an aerobic lagoon for receipt of these wastes.

The anaerobic cell is designed on the basis of 30 lbs. $BOD_5/1000\ ft^3$, with the aerobic cell designed on the basis of 35 lbs. BOD_5/acre/day, assuming 60% reduction of BOD_5 in the anaerobic cell. The volumetric flow from the household wastes is considered to be 75 gpcd. As is the case for any waste treatment facility, permits are required from the department of health for construction and operation of dairy farm lagoons.

The significance of quantity and quality of waste from any source is a relative item, dependent upon the receiving watercourse and its flow characteristics.

It has been necessary to require water pollution control facilities for very small animal installations including individual dairy farms.

Outlook for Animal Feedlots

Great strides have been made in developing Kansas as a major beef producer and red meat producer in general. In 1964 the annual average meat consumption in the United States was approximately 100 pounds per person. In 1967 the average consumption reached to between 110-115 pounds per person. The present growth rate of our nation's population together with annual meat consumption averages indicates there will be an increasing demand for slaughter cattle at a rate of several hundred thousand head per year.

Nutritional advance in feeder cattle is significant. Approximately five years ago feeders were providing 30 lbs. of feed per day with a weight gain of 2 to 2-1/2 lbs. per day. In 1967, the feeder was providing approximately 23 lbs. of feed per day and getting a 3 to 3-1/2 lb. weight gain.

We can see nothing but continued increase in the number of commercial feedlots and feeder cattle. Nationally, Kansas ranks Number 1 in silage and sorghum grains. Additionally, we rank Number 1 in the production of wheat which can be an important feed element dependent on market prices. Farmers in general are being encouraged to diversify operations and bring along calf crops to be finished in commercial lots.

In 1967, Kansas plants killed 1.6 million cattle. In 1968, projections were that Kansas will have killed 1.6 million cattle even though for several months some major kill plants were out of operation for expansion purposes. The department of health obtains information on meat processing plants due to the requirements of water quality control. Slaughter plants in Kansas, both large and small, approach 300 in number. At this time there are 15 major slaughter plants (two of which are under construction and one in planning) which have a total annual capacity of killing in excess of 2.6 million cattle.

It is our estimate that cattle feedlots and feeder cattle will more than double in the next few years. Increase in the numbers of hogs are not expected to be as great as in cattle but still should be significant. The numbers of sheep are expected to remain relatively stable. The problems of environmental control will be magnified but we are confident that success will prevail if there is cooperation among all concerned.

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	UNITED STATES				KANSAS					
Year	No. States Reporting	*Total No. Fish Kills Reported	Total No. Fish Killed (millions)	Max. Single Fish Kills (millions)	Total No. Fish Kills		Total Fish Killed (mil.)		% Total Fish Killed Attributed to Feedlots	No. Cattle Comm. Feedlots 1 Jan.
					All Causes	Feedlots	All Causes	Feedlots		
1960	36	149	6.023	5.0	No Report					58,000
1961	45	263	14.91	5.39 5.0	4	1	No Report		-	88,000
1962	37	233	6.2	3.2	1	0	0.005	0	0	99,000
1963	38	300	6.8	2.0	9	2	0.14	0.12	89	150,000
1964	40	385	17.9	2.0 1.0 7.9 2.0	26	16	1.35	1.12	82	183,000
1965	44	446	11.4	3.0 1.25 1.2	6	5	0.57	0.57	99	200,000
1966	46	372	8.7	1.0 1.0 0.73	23	16	1.2	1.0	90	260,000
1967	40	303	11.2	6.6	29	18	1.0	1.0	94	311,000
1968					16	3	0.4	.03	7	338,000

*Only those reports giving numbers of fish killed.

FISH KILLS BY ANIMAL WASTES

Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/l	Min. DO mg/l	Max NH_3 as (N) mg/l	Max. Total Coliform
12 May 61		Spring Creek WaKeeney	300	1.0					
11 June 61		Arkansas Dodge City		0.96	266				
18 June 61		Arkansas Dodge City		1.20	111				
15 June 61		Slate Creek Wellington		1.32					
15 June 62		Pawnee Burdett	5,000	1.23	26				
25 June 62	25 June 62	Slate Creek Wellington		0.73		470.	0.0	58.	
26 Aug 62	31 Aug 62	Cottonwood Emporia							
23 Nov 62	26 Nov 62	Fox Creek Strong City			400	90.	0.8	12.	$1.6x10^6$
27 May 63	29 May 63	Cottonwood Emporia		1.25	280	30.	0.0	3.3	$2.4x10^6$
15 Jun 63	15 Jun 63	Whitewater Potwin	1,000	1.09	22	345.	0.0	28.	$95x10^6$
17 Jun 63	25 Jun 63	S. Fork Ninnescah - Pratt	8,000	1.78	93	680.	0.0	53.	$1x10^6$
10 Jun 63	10 Jun 63	Owl Creek Yates Center	500	2.30					

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Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/l	Min. DO mg/l	Max NH_3 as (N) mg/l	Max. Total Coliform
15 July 63	15 July 63	Level Creek Herington		1.0					
19 July 63	26 July 63	N. Br. Hackberry Gove	2,000	0.73		6.5	2.2	2.2	
21 Oct 63	25 Oct 63	Level Creek Herington	115,000	2.8		90.	0.0	5.6	0.5×10^6
7 Nov 63	7 Nov 63	Level Creek Herington					0.0		
11 Nov 63		Level Creek Herington							
5 Apr 64	14 Apr 64	Spring Creek Fairview	31,500	0.77	13		0.0		
11 Apr 64	13 Apr 64	Elk Elk City	1,000	0.17	12		2.6		
22 Apr 64	22 Apr 64	Owl Creek Yates Center		0.5		70.	0.0	26.	
26 Apr 64		Pawnee Rozel	1,500	0.61	26				
1 May 64	1 May 64	Owl Creek Yates Center				120	0.0	13.	
11 May 64		Buckner Creek Jetmore	100	0.63	98				
21 May 64		Farm Pond Haviland	100	0.56					
28 May 64	28 May 64	Elk River Elk City	2,000	1.56	540	8	0.7	1.4	
30 May 64		Wet Walnut Great Bend	20,000	0.87	25				

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Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/1	Min. DO mg/1	Max NH_3 as (N) mg/1	Max. Total Coliform
31 May 64	2 June 64	Arkansas Dodge City	365,000	1.08	66		3.9	3.8	
	1 June 64	Cottonwood Emporia		2.40	407	4.8	6.3	1.3	4.3×10^5
8 June 64		Sawlog Creek Dodge City							
22 June 64	22 June 64	Wet Walnut Great Bend		1.03	16	67.	0.0		
23 June 64		Otter Creek Climax (Hogs)	500	0.70	16				
30 June 64		S. Cottonwood Hillsboro	2,000	1.18					
31 July 64		Arkansas Dodge City	3,000	3.28	98				
14 Aug 64	14 Aug 64	Bachelor Creek Elk City		1.73		220.	0.0	21	4.6×10^6
19 Aug 64	19 Aug 64	Bachelor Creek Elk City		0.1		230.	0.0	22	
20 Aug 64	20 Aug 64	Arkansas Bucklin	2,000	2.71	426	85.	0.0		
20 Aug 64		S. F. Ninnescah Pratt		1.94		210.	0.0		
20 Aug.64		Whitewater Potwin	55,900	1.19	10				
29 Aug 64	31 Aug 64	Spring Creek Fairview	40,000	1.25		125.	0.0	5.7	
5 Sept 64	5 Sept 64	Wet Walnut Great Bend				360.			

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Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/l	Min. DO mg/l	Max NH$_3$ as (N) mg/l	Max. Total Coliform
11 Sept 64		Cottonwood Cedar Point	18,000	0.52	15				
14 Sept 64	17 Sept 64	Cottonwood Strong City	340,000	1.94	38	43	0.0	14	2.3×10^6
15 Sept 64		Pawnee Larned	2,000	0.70					
17 Oct 64	17 Oct 64	Labette Creek Parsons					2.6		
30 Oct 64	30 Oct 64	Cottonwood Emporia	240,000	2.69	50	35	0.0	7.5	24×10^6
17 May 65		Gooseberry Cr., Newton	1,000						
21 May 65		Whitewater Potwin		0.84	0.5	1750	0.0	80.	
6 June 65	6 June 65	Spring Creek Fairview	45,000	0.79	2.0	45	0.0	5.6	4.3×10^6
6 June 65	7 June 65	S. F. Ninnescah Pratt	20,000	3.52			0.0		
7 June 65		Arkansas Dodge City	500,000	1.15					
20 July 65		Fall River Eureka	5,000	0.80					
15 Aug 65	17 Aug 65	Labette Cr. Parsons	3,000	0.59	2.0	60	0.0	1.4	43×10^6
20 Aug 65		S. F. Ninnescah Pratt		0.54					
23 Aug 65		Salt Creek Hutchinson (hogs)							

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Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/1	Min. DO mg/1	Max NH$_3$ as (N) mg/1	Max. Total Coliform
15 Mar 66		Cottonwood- Neosho-Emporia	300,000		288				
17-20 May 66		Spring Creek Fairview	10,000						
20 May 66	27 May 66	Cottonwood Cedar Point	100,000		186		4.5		
1 June 66		Four Mile Cr. Augusta	500	1					
26 June 66	27 June 66	Spring Creek Fairview	10,000			55.	0.0	2.4	1.8x10^6
21 July 66		S.F. Ninnescah Pratt	60,000	3					
23 July 66		S. Walnut Creek Dighton	2,000						
8 Aug 66		Big Creek Yocemento	2,000						
13 Aug 66		Arkansas Dodge City	5,000		71				
25 Aug 66		Solomon Beloit (Hogs)	5,000		76				
26 Sept 66		Cottonwood Emporia	300,000		119				
26 Sept 66		Cottonwood Cedar Point	35,000		22				
28 Sept 66		Cottonwood Saffordville	20,000		25				

Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/l	Min. DO mg/l	Max NH_3 as (N) mg/l	Max. Total Coliform
2 Feb 67	3 Feb 67	Neosho Emporia	225,000	0.5	40	50.	0.4	6.4	
27 Mar 67	27 Mar 67	Cottonwood Strong City	25,000		27	290.	0.0	17.	17×10^6
31 Mar 67	4 Apr 67	Cottonwood Cottonwood Fa.	80,000		41	21.	0.0	2.6	
31 Mar 67	4 Apr 67	Cottonwood Emporia	90,000		63	18.	2.2	1.9	
1 Apr 67	3 Apr 67	Four Mile Cr. Whitewater				100.	0.0	7.2	
3 Apr 67	4 Apr 67	Lightning Cr. Girard				175.	0.0	4.6	
10 Apr 67		Doyle Creek Peabody	1,000	1.					
12 Apr 67		S. F. Ninnescah Natrona	200						
12 Apr 67	14 Apr 67	Cottonwood- Neosho-Emp.	50,000		58	105.	0.0	7.0	
15 May 67	17 May 67	Cottonwood- Neosho-Emp.	425,000		49		0.0	11.	
31 May 67		Doyle Creek Peabody	25,000						
4 June 67	7 June 67	Cottonwood Emporia			58	55	0.0	8.3	
14 June 67	24 June 67	Jester Creek Newton	50,000	1.		19	3.5	2.6	

Date of Kill	Date of Samples	River and Location	Est. No. Fish Killed	Max. Day Rain Inches	River Flow cfs	Max. BOD mg/1	Min. DO mg/1	Max NH_3 as (N) mg/1	Max. Total Coliform
21 June 67		S. Walnut Cr. Dighton	5,000						
8 July 67		Solomon Beloit (Hogs)	2,000						
26 July 67		Solomon Glen Elder (Hogs	4,000						
18 Sept 67	18 Sept 67	Whitewater Potwin				400	0.0	215	$37x10^6$

FEEDLOT FISH KILL INVESTIGATION
Cottonwood River, Kansas
30 October 1964

Rainfall 28 October 1964
240,000 Fish Killed

Approx. River Mile	D. O. mg/l	BOD_5 mg/l	NH_3 (as N) mg/l	Cl^- mg/l	Total Coliform $x10^6$	Fecal Coliform $x10^6$	Fecal Strep. $x10^6$
-8.9	9.2	9.5	0.40	79	0.0023	0.0023	0.002
-1.5	5.9	7.2	0.74	51	0.023	0.0043	0.018
0.0 Trib. to R. from feedlot	0.0	140.	5.4	159	2.3	4.3	4.0
0.9	0.8	8.5	0.56	61	0.23	0.23	0.48
Secondary effluent from 0,000 P. E. city between these stations		30-40					
2.7	2.0	14.	2.8	68	0.93	0.93	0.60
5.4	0.0	32.	4.4	75	4.3	4.3	19.0
10.8	0.0	30.	4.8	75	24.0	24.0	10.0
12.3 Joins main stem Neosho above Cottonwood	2.7	5.5	0.34	75	0.0093	0.0093	0.041
13.9	0.0	30.	5.3	77	2.3	2.3	27.0
14.9	0.0	35.	5.4	75	0.75	0.23	3.4
15.5	0.0	21.	7.5	68	0.23	0.093	0.025
16.8	1.1	4.8	2.8	58	0.0075	0.0075	Missed
19.8	3.0	3.8	3.7	64	0.0023	0.0023	Missed

FEEDLOT FISH KILL INVESTIGATION
Spring Creek-Walnut Creek, Kansas
6 June 1965

45,000 Fish Killed

Approx. River Mile	D. O. mg/l	BOD_5 mg/l	NH_3 (as N) mg/l	Cl^- mg/l	Total Coliform $x10^6$	Fecal Coliform $x10^6$	Fecal Stre $x10^6$
4.0	8.5	0.8	0.4	7.0	0.00093	0.00015	0.00[illegible]0
3.8 Trib. from feedlot joins Spring Cr.	0.0	65.	18.	95.	9.3	4.3	23.0
3.4	6.9	4.0	0.78	3.0	0.093	0.023	0.10
3.0	1.9	45.	5.6	32.	4.3	1.5	5.2
1.8	0.0	30.	2.9	28.	0.93	0.23	0.59
1.4	5.7	1.0	0.48	6.0	0.0043	0.0043	0.00[illegible]9
0.0 Mainstem Walnut Cr. downstream mileage							
1.7	7.4	0.8	0.45	17.	0.0043	0.00093	0.00[illegible]3

Feedlot Runoff Characteristics
No Retention Ponds

Date	Location	BOD_5 mg/l	NH_3 as (N) mg/l
1 May 1964	Yates Center	2800	225
11 Apr 66	Saffordville	8000	
11 Apr 66	Strong City	4650	
11 Apr 66	Strong City	5700	
29 July 66	Saffordville	3550	285
3 Apr 67	Strong City	1830	41
3 Apr 67	Strong City	GT 1950	102

Feedlot Retention Pond Effluent Characteristics

Date	Location	BOD$_5$ mg/l	NH$_3$ as (N) mg/l	NO$_3$ mg/l	Cl mg/l
7 Nov 63	Herington	320	24		
24 Jan 64	Primary Cell Potwin	2500	232	62	306
24 Jan 64	Secondary Cell Potwin	2050	225	71	364
24 Jan 64	Primary Cell Potwin	72	22	7.5	146
24 Jan 64	Secondary Cell Potwin	62	20	8.8	147
1 May 64	Primary Cell Yates Center	2800	225	9.7	1610
21 May 65	Secondary Cell Potwin	5500	400	2.0	475
21 May 65	Primary Cell Potwin	330	41	5.3	195
21 May 65	Secondary Cell Potwin	60	25	4.3	187
6 June 65	Primary Cell Fairview	700			
18 Jan 66	Secondary Cell Potwin	780	220	16	275
25 Sept 67	Secondary Cell Potwin	630	310		
19 June 68	Secondary Cell Potwin	600	350		
19 Aug 68	Secondary Cell Potwin	390	230		

Kansas State Department of Health
Environmental Health Services

CHAPTER 28. STATE BOARD OF HEALTH REGULATIONS

ARTICLE 18. AGRICULTURAL AND RELATED WASTES CONTROL

28-18-1. DEFINITIONS

For purposes of the regulations in this article, the following words, terms and phrases are hereby defined as follows:

(a) The words "confined feeding" shall mean the confined feeding of animals for food, fur, or pleasure purposes in lots, pens, pools or ponds which are not normally used for raising crops and in which no vegetation, intended for animal food, is growing. This will not include a wintering operation for cows in lots or on farming ground unless the operation causes a pollution problem.

(b) The words "confined feeding operation" shall mean (1) any confined feeding of 300 or more cattle, swine, sheep, or horses at any one time, or (2) any animal feeding operation of less than 300 head using a lagoon, or (3) any other animal feeding operation having a water pollution potential, or (4) any other animal feeding operation whose operator elects to come under these regulations.

(c) The term "operator" shall mean an individual, a corporation, a group of individuals, joint venturers, a partnership, or any other business entity having charge or control of one or more confined feeding installations.

(d) "Food animals" shall mean fish, fowl, cattle, swine, and sheep.

(e) "Fur animals" shall mean any animal raised for its pelt.

(f) "Pleasure animals" shall mean dogs and horses.

(g) The words "waste retention lagoon" or "retention ponds" shall mean excavated or diked structures, or natural depressions provided for or used for the purpose of containing or detaining animal wastes consisting of body excrements, feed losses, litter, cooling waters, wash waters, whether separately or collectively, or any other associated materials detrimental to water quality or to public health, or to beneficial uses of the waters of the state. A waste retention structure shall not be construed to be a treatment facility and discharges of waste water therefrom shall not be allowed except as authorized by regulations 28-18-3 and 28-18-4.

(h) The words "waste treatment facilities" shall mean structures and/or devices which stabilize, or otherwise control pollutants so that after discharge of treated wastes, water pollution does not occur and the public health and the beneficial uses of the waters of the state are adequately protected.

(i) The words "water pollution control facilities" shall mean waste retention lagoons, retention ponds, or waste treatment facilities.

(j) The term "department" shall mean the Kansas State Department of Health. (Authorized by K.S.A. 65-164, K.S.A. 65-171f, K.S.A. 65-165 as amend., K.S.A. 65-167 as amend., K.S.A. 65-171d as amend., K.S.A. 65-171h as amend.; effective 31 May 1967.)

28-18-2. REGISTRATION AND WATER POLLUTION CONTROL FACILITIES PERMITS.

(a) Effective July 1, 1967, the operator of any newly proposed confined feeding operation as defined in regulation 28-18-1(b) must register with the Kansas State Department of Health prior to construction and operation of the lot, pen, pool or pond. The operator of any existing confined feeding operation as defined in regulation 28-18-1(b) must register by January 1, 1968. Application for registration shall be made on a form supplied by the department.

(b) Applicants shall submit the completed application form to the department together with supplemental information regarding general features of topography, drainage course and identification of ultimate primary receiving streams. Additional information which may be deemed necessary for satisfactory evaluation of the application may be required by and shall be submitted to the department.

(c) If in the judgment of the department, a proposed or existing confined feeding operation does not constitute a potential water pollution problem because of location, topography, or other reasons, provision of water pollution control facilities will not be required.

(d) If in the opinion of the department a confined feeding operation does constitute a water pollution potential, or if water pollution occurs as a result of any confined feeding operation, the operator shall provide water pollution control facilities which shall be constructed in accordance with plans and specifications approved by the department.

(e) Water pollution control facilities shall not be placed in use until a permit has been issued. Permits for water pollution control facilities will be issued by the executive secretary of the Kansas State Board of Health upon satisfactory completion of construction in accordance with plans and specifications approved by the department. Water pollution control facilities permits shall be revocable for cause on thirty days' written notice. If a water pollution control facilities permit is revoked, the owner or operator of the confined feeding operation involved shall be allowed to finish feeding existing animals in the lot, pen, pool or pond at the time of revocation but shall not place or allow to be placed in the lot, pen, pool or pond any other animals until the minimum requirements for water pollution control as set forth in regulations 28-18-3 and 28-18-4 have been met and a new water pollution control facilities permit has been issued. (Authorized by K.S.A. 65-164, K.S.A. 65-171f, K.S.A. 65-165 as amend., K.S.A. 65-166 as amend., K.S.A. 65-167 as amend., K.S.A. 65-171d as amend., K.S.A. 65-171h as amend.; effective 31 May 1967.)

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28-18-3. REQUIREMENTS FOR FACILITIES

Water pollution control facilities required shall be kept at the minimum requirements stated in the following paragraphs; provided that when site topography, operating procedures, and other available information indicate that adequate water pollution control can be effected with less than the minimum requirements, the minimum requirements may be waived; provided further that if site topography, operating procedures, experience, and other available information indicate that more than the minimum requirements will be necessary to effect adequate water pollution control, additional control provisions may be required.

(a) CATTLE: The minimum water pollution control facilities for the confined feeding of cattle shall be retention ponds capable of containing three inches of surface runoff from the feedlot area, waste storage areas, and all other waste contributing areas. Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Waste retained in detention ponds shall be disposed of as soon as practicable to insure adequate retention capacity for future needs.

(b) SWINE: Waste retention lagoons for swine feeding operations may be allowed in lieu of waste treatment facilities. Waste retention lagoons must be capable of retaining all animal excreta, litter, feed losses, cooling waters, wash waters, and any other associated materials and shall additionally be capable of retaining three inches of rainfall runoff from all contributing drainage areas. Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Provision must be made for periodic removal of waste material from retention lagoons.

(c) SHEEP: The minimum water pollution control facilities for the confined feeding of sheep shall be retention ponds capable of containing three inches of surface runoff from the confined feeding area, waste storage areas, and

and all other waste contributing areas. Diversion of surface drainage prior to contact with the confined feeding area or manure or sludge storage areas shall be permitted. Waste retained in detention ponds shall be disposed of as soon as practicable to insure adequate retention capacity for future needs.

(d) OTHER ANIMALS: Each confined feeding operation registered involving other animals shall be evaluated on its own merits with regard to the water pollution control facilities required, if any. The confined feeding of other animals shall not cause or lead to the pollution of the waters of the state by runoff water from confined feeding areas, release or escape of water from pools or ponds, improper storage or disposal of waste materials removed from the confined feeding area, or by any other means.

(e) Waste treatment facilities shall be designed, constructed, and operated in conformance with the provisions of regulation 28-18-4. If waste treatment facilities consist only of pond or lagoon type structures, there shall be a minimum of two such structures for series operation.

(f) Other methods of water pollution control shall be permitted where in the judgment of the department effective results will be obtained. (Authorized by K.S.A. 65-164, K.S.A. 65-171f, K.S.A. 65-165 as amend., K.S.A. 65-166 as amend., K.S.A. 65-167 as amend., K.S.A. 65-171d as amend., K.S.A. 65-171h as amend.; effective 31 May 1967.)

28-18-4. OPERATION OF FACILITIES.

(a) The water pollution control facilities shall be operated and maintained so as to prevent water pollution and to protect the public health and the beneficial uses of the waters of the state.

(b) Waste discharges from retention ponds, lagoons, or waste treatment facilities into any watercourse shall be in conformance with the water quality requirements of the appropriate river basin criteria as set forth in chapter 28, article 16 of regulations adopted by the Kansas State Board of Health and regulation 28-18-3.

(c) Waste materials removed from retention ponds, waste treatment facilities, and/or confined feeding areas shall be disposed of or stockpiled in a manner which will not contribute to water pollution. Wastes may be used for irrigation or spread on land surface and mixed with the soil in a manner which will prevent runoff of wastes. Other methods of disposal of wastes from retention ponds, retention lagoons, waste treatment facilities, and/or confined feeding areas shall be evaluated and permitted if in the judgment of the department effective water pollution control will be accomplished. (Authorized by K.S.A. 65-164, K.S.A. 65-171f, K.S.A. 65-165 as amend., K.S.A. 65-166 as amend., K.S.A. 65-167 as amend., K.S.A. 65-171d as amend., K.S.A. 65-171h as amend.; effective 31 May 1967

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Management of Animal Feedlot Wastes

* * * *

LAND SPREADING AS A DISPOSAL PROCESS

G. E. Smith*

Beef and pork produced in the mid-continent area has furnished a major portion of the protein consumed by the American people. Per captia consumption of meat is greater than in most countries. A significant portion of the housewife's grocery dollar goes for these products from the farms and feedlots of the midwest. Future demands for meats and animal proteins will grow.

Since our forefather's day farm production in the midwest has been tied to humus, a thin layer on the surface of soils. This organic material supplied over 95 percent of the nitrogen and about half of the phosphorus required by crops. Until 15-20 years ago the manure from farm animals was considered essential for maintaining the productivity of land. Many of the early field experiments (including those on Sanborn Field--established in 1889--on the University of Missouri Campus-Columbia) were devoted to experiments with manure. In the 1939 Yearbook of Agriculture the section** on Farm Manures states: "One billion tons of manure, the annual product of livestock on American farms, is capable of producting $3,000,000, 000. worth of increase in crops.... The crop nutrients it contains would cost more than six times as much as was expended for commercial fertilizers in 1936. Its organic matter content is double the amount of soil humus annually destroyed in growing the nation's grain and cotton crops...." Textbooks on soil fertility and management written prior to the start of the last decade devoted considerable space to methods of handling manure that would prevent volatilization of nitrogen and losses of phosphorus and other nutrients required by crops that might be lost by leaching or runoff. Numerous experiments were quoted where a ton of manure would produce increases in crop yields worth two-three dollars per ton. However, recent changes in chemical technology and crop and livestock production has made animal manures, in many areas, unwanted wastes that can cause both water and air pollution, and create disposal problems.

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* Director Water Resources Research Center and Professor of Agronomy, University of Missouri.

** U.S.D.A. pp 445-461.

Chemical Developments Have Provided Lower Cost Fertilizers

Since the late 1940's fertilizer manufacture has become a major chemical industry. The petroleum industry, with ample capital, has become the major supplier of fertilizers. The term "petro-chemical" is almost synonymous with the synthesis of anhydrous ammonia from air and natural gas. Since elements other than nitrogen are required by crops, many of the oil companies have also become suppliers or distributors of the other elements essential in plant nutrition. Over production of chemical fertilizers has made these compounds a "best buy" for farmers. At present anhydrous ammonia can be purchased at one-fourth or one-third the cost of other forms of chemical nitrogen available in former years when farm manures were the nucleus of many soil fertility programs. Phosphorus and potassium can also be purchased at prices comparable to those of more than a decade ago.

Major increases in the use of chemical fertilizers has taken place in the fertile grain and livestock producing area of the midwest. Animal manures are still considered valuable in improving soil tilth and crop yields. However, manures alone will not give as high or economically produced yields as will the proper balance of essential nutrients in chemical form. Claims of other benefits from manures, than nutrient content, have not been substantiated. Shortages of farm labor, the low cost of chemical nutrients, the greater production of crop residues and changes in livestock feeding practices has made animal wastes a necessary evil to business-minded farmers.

Crop Production Methods Altered

Chemical nitrogen (balanced with proper mineral additions) has replaced rotations where legumes were turned under as a source of nitrogen for grain crops. Benefits to soil tilth from organic additions that permit greater water penetration and less erosion and runoff, have been offset by the more vigorous growth of properly fertilized row crops. Erosion from liberally fertilized corn fields can be lower, than from management systems where a rotation with legume crops is practiced and little chemical fertilizer is added. The amount of residues returned under these new management systems is greater than was ever added by farm manure and the smaller crop residues produced without chemicals. Crops of corn that produce 100 or more bushels of grain annually will add 3--4 tons of dry matter in residues. Where corn is grown continuously and only the grain removed the annual return of residues adds more organic material to the soil than is obtained from most rotation systems where hay is removed or where forage crops are grown for green manures. Total return is greater where a cash crop is harvested each year than where a portion of the land is utilized for "soil-improving" crops.

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Livestock Production Methods Changing

Large specialized cattle and hog feeding operations are increasing in size and number although probably not as rapidly in Missouri as in some other states. These large operations can provide a steady supply of uniform and desired product and produce at a lower unit of profit than can the smaller farm operator. Where the livestock feeding is only a part of a general farm operation and most of the grain is produced, manure is still returned to the fields. Manure spreading is done when convenient with regular labor. However, where the acreage involved is small, livestock numbers large, and most of the feed is purchased, large amount of manure will accumulate. In many cases the operator may have no fields for spreading. Although this waste is of value when applied to the soil the profit from handling and spreading is frequently less than the returns from applying chemical nutrients to crops. Manures from feedlots or from confinement storage may have lost so much nitrogen that the material is a "poor buy" for grain farmers in the area. When rains flush these wastes into streams the oxygen levels can be reduced or the growth of aquatic plants stimulated. Returning these wastes to soils producing crops is probably the most logical method of disposal. However, the feedlot operator and meat consumers must consider this disposal as an added cost of the product rather than a by-product that can add profit to the feeding operation or lower the cost of the finished product to the consumer.

Composition of Manures and Chemical Changes

Traditionally industry has looked to agriculture as a potential market for waste products (many worthless or harmful to plants). Fortunately the wastes from animal feeding can be utilized in crop production. As large amounts of feedlot manures or fluid materials are applied to valuable crop land, the composition and soil reactions with these products need attention as yields and crops composition may be adversely affected by improper use. Relatively little information is available on the variation in composition of feedlot or liquid manures. Differences in composition have made difficult the processing to fullfill inspection laws in selling to the home garden trade. However, most of the soluble nitrogen in both feedlot and liquid manures are lost by volatilization or denitrification when temperatures are above 60°F. Much of the potassium from the feedlot wastes will have been leached in humid areas. Most of the information available on manure composition and soil reactions is older data that pertains to the use of stall manure as a soil amendment.

Manures vary greatly in composition, but it is generally considered that a ton of stall or barnyard manure will contain about 10 pounds of total N, 5 pounds of total P_2O_5 and ten pounds of K_2O.

Manure contains inadequate phosphorus to serve as a optimum amendment for most Missouri soils. Most of the phosphorus and more than one-half of the nitrogen is in the solid portion, while potassium is largely secreated in the urine. The kind of animal, feed composition, litter and method of handling influences the composition.

The experiences of some sound thinking grain producers in using feedlot or liquid manures as soil amendments have been disappointing. Some are not interested in having the material applied to their land at no charge. Apparently, in some seasons, so much of the nutrients have been lost before applying, the effect on crop growth is much less than manures from stalls or dairy operations. The total fresh wastes from swine and cattle will contain 2/3 to 3/4 water. Manure from large feedlots that has been subjected to precipitation and alternate drying will have a lower content of nutrients and a higher content of dry matter. When handled in liquid form from pits the solids content would probably range from 20-30 percent.

When manure is first dropped it undergoes rapid fermentation. Aerobic decomposition occurs with heat, carbon dioxide and ammonia being released to the atmosphere. Nitrogen, either as ammonia or elemental nitrogen, and carbon dioxide from decomposing organic matter account for the principal losses due to volatilization. The nitrogen in manure is chiefly in the form of urea, undisgested protein, or microbial tissue. The urea readily undergoes hydrolysis to ammonium carbonate, and this reaction may go to completion within a few days. The ammonium carbonate is unstable and tends to form gaseous ammonia and carbon dioxide under open feedlot conditions, during warm weather. The change to ammonia is greater at higher temperatures. Most of the urea nitrogen would probably be lost to the atmosphere in less than a week. Drying speeds ammonia loss. Losses are also increased by freezing since the concentration of the solution is increased by the crystallization of water. Manure spread on a field in freezing weather has been found to lose as much as one-half of the ammonia in a few days. When liquid or semi-solid manure is allowed to accumulate in pits there will be anaerobic reactions. Much of the soluble nitrogen will be lost by denitrification. The solubility of phosphorus will probably increase. Concentration of other minerals should be similar to quantities in fresh manure, unless water is added to increase fluidity.

Some of the ammonia released in open feedlots will be nitrified (or absorbed on litter if bedding is used). Nitrification requires oxygen. More nitrification will probably occur under feedlot conditions than where manure is piled or trampled in barns.

Where the temperature rises to 120-140°F, nitrifying organisms will be killed. Where nitrates are formed and leach into a mass of material or wet soil anaerobic decomposition will occur and elemental nitrogen may be lost by denitrification. Measurements have been made showing that cow manure stored in loose heaps in the open for three, six and nine months lost 24, 34 and 38 percent of the total nitrogen respectively*. Where measurements have been made on manure rotting (a condition not too different than trampling in a feedlot) from one-fourth to one-half of the nitrogen would be lost in a few weeks. Phosphorus solubility would probably increase. Most other mineral elements would change but little except that with leaching the potassium and some other minerals would be lost.

The undigested feed protein and microbial protein in feces are somewhat resistant to further decomposition and the nitrogen becomes soluble only under prolonged microbial action. Experiments have shown some of this nitrogen may not become available to plants until a year or more after application to soil. Much of the undesirable odor from feedlots is derived from the anaerobic decomposition of nitrogen containing compounds.

The rate and nature of carbohydrate decomposition in manure depends greatly on the degree of aeration. It would be expected that the rate would be much higher under open feedlot conditions than where measurements have been made on compacted manure in barns.

The solid portion of manure is largely carbohydrate compounds, cellulose, hemicellulose, lignin and some portions of the feed that was not disgested. The lignin and protein combine to form complexes similar to the humus compounds produced in soils. These compounds are only slowly available to plants.

Reactions of Manures in Soils

Management practices with manure to return maximum amounts of nutrients for crops, emphasize the need for adequate bedding to absorb liquids, and the use of acids or phosphates to react with ammonia. Maximum conservation is obtained by hauling the manure daily and immediately plowing or disking into the soil. Such practices have been followed by conservation minded farmers with Grade A dairies where sanitation must meet public health requirements.

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* Ohio Agr. Exp. Sta. Bul. 605, 1939

Spreading of manure on snow or when the soil is frozen is convenient. However, with snow melt and runoff substantial pollution of streams may result. Some losses of nitrogen have been reported of about 8 percent in 12 hours when manure was spread on a soil at a temperature of 68°F and the air was still. However, when a wind movement of 8½ miles per hour was provided losses increased to more than 25 percent. After 3½ days the losses had increased to 32 percent in still air and about 36 percent when there was air movement. Higher percentage losses have been found when filter paper has been soaked with fermented urine.

When manures are incorporated in soils, the reactions similar to those which occur in barns or feedlots will continue. Simple organic compounds containing nitrogen will release ammonia which will be absorbed on the soil exchange complex. If temperatures are below 55-60°F the nitrogen will remain as ammonia. With higher temperatures nitrates will be formed and will be subject to leaching unless absorbed by growing crops. Inorganic phosphorus added or formed will react with iron, aluminum, calcium or other cations. The reaction will be influenced by soil pH. Potassium calcium, magnesium and the trace elements will be held by exchange bonding on soil colloids or in some chelated form.

All of these reactions that occur when manures are added to soil are similar to those that have permitted the productive soil of the corn belt to develop from the mineral-rich parent material. Although the nutrients contained in the manure may not be a bargain at the price of chemical fertilizer nutrients today, the effect of the added humus will be of some benefit on most soils. Where subsoils have been exposed by erosion or by other means (land forming, terracing) the manure is valuable to improve aeration and oxidation, increase water penetration and reduce erosion.

Rate of Application

Where barnyard manures have been applied to crops, yields have not substantially increased when more than 6-10 tons per acre are applied annually. It is probable that feedlot or liquid wastes could be applied at heavier rates than barnyard manure because of the lower soluble nitrogen content. In some cases supplemental chemical nitrogen might also be required to produce optimum crop yields. Best results have been obtained when the manure is supplemented with phosphate fertilizer. Excessive rates of manure addition may result in abnormal vegetative growth and lodging of some crops.

Where drouth or excessively wet soil conditions prevail during the growing season, the manure may not decompose and anaerobic decomposition could produce compounds that are toxic to plants. Too much organic material in the root zone could result in drying of the soil so germination and stand could be adversely affected.

Pasture or silage crops produced on old feeding areas may contain so much nitrate that the feed is toxic to ruminants. Agronomists frequently recommend corn or sorghum produced on heavily manured areas should be harvested for grain. Crops for silage should be grown on soils receiving chemical fertilizers so the amount of nutrients available during the critical growing season can be more accurately controlled.

Crops Removed of Nutrients Greater Than Fertility Additions

Despite the great increase in use of chemical fertilizers in recent years, crops in this country are still removing from soils more minerals and nitrogen than are being returned. Average amounts of chemical nutrients applied per acre in this country are much less than is used in many European countries. Conservation of nutrients from animal feeding operations will not only reduce pollution, but can aid in effecting a balance between nutrient return to soils and crop removal of essential elements.

SUMMARY

1. Returning feedlot and animal confinement wastes is an effective disposal method and can increase crop yields. Feedlot wastes and liquid manures will usually have a lower nutrient content then will fresh or barnyard manures. Most of the soluble nitrogen will be volatilized as ammonia or denitrified before application. Potassium will be leached from feedlots in region with high rainfall.

2. In many situations the cost of applied nutrients in chemical fertilizers will be less than the cost of labor and equipment for spreading feedlot or liquid wastes.

3. For optimum crop yields, chemical nutrients will frequently be needed to supplement livestock wastes.

4. Where substantial amounts of feedlot or liquid manures are to be applied to soils, chemical analyses should be made to determine the actual amount of plant nutrients that will be added.

5. Corn and grain sorghum are the crops in Missouri that can best utilize heavy applications of manures. These crops, when heavily manured should be harvested for grain. These species, when grown for silage with excess manure treatment may contain high levels of nitrate.

6. Most retention in soils, most desirable soil reactions and the most efficient crop returns will be obtained when rates of manure application are no more than 10 tons per acre annually.

7. Manures should be incorporated into soils as soon as possible after applications.

8. When the location of large feeding operation is being planned, sufficient acreage of cropland should be available so that some fields will be available in most months of the year for spreading wastes.

9. When the economics of large livestock feeding operations are being considered, disposal of wastes may be a cost of operation, rather than a by product that will produce income.

10. Improved equipment is needed for handling large amounts of liquid manure and feedlot wastes, to minimize odors and to efficiently spread under a wide range of conditions.

Design for Feedlot Waste Management
"Using Feedlot Waste"

Lynn R. Shuyler, P. E.
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The basic idea in the past of management of animal waste has always been for this waste to be applied to the land. This was a simple matter when the large herd roamed the free range or even today, when we have cattle on pasture. The problem of the farmer, who fed cattle on the farm in the past, also had no disposal problems. As many of us can remember, I am sure, when we spoke of manure disposal, this meant getting out the manure spreader, and loading it to haul the manure to the field. This was a simple matter for the man who had only a few head on feed. This type of fertilizer was needed on most farms to treat that "poor" sand hill or that "bad" piece of land.

Today the cost of moving manure onto the land is usually more than the benefits derived from the manure. Even the farmer-feeder would find it cheaper to apply commercial fertilizer than to haul the manure on his land. The most pressing problem today is not the farmer-feeder, but the larger feeder or feedlot. We are not dealing with 20 to 50 head of cattle in one location, but we are talking in terms of many hundreds or several thousand head of cattle in one location. It is obvious that this is not a one-spreader operation for the feedlots.

The feedlot operator is stuck with the problem of how to get rid of tons and tons of dry waste from the lot. In Kansas, he must also control and dispose of any liquid waste from his feedlot.

It is the opinion of many of us in Kansas, that the best way to dispose of this material is to apply it to agricultural land. It is not a point in most cases of making money from animal waste, but one of breaking even or losing as little money as possible disposing of the waste from the lot. If you look very closely at most industrial plants, you will find that they are very happy to get rid of their waste or scrap at a fraction of its value, as long as it does not cost the plant very much. They figure this cost as a part of the overhead involved in their operation. I think this is the way feedlots are going to have to solve the problem of dry waste. Some lots today will load dry waste for the farmer, just to get him to haul it away. This seems to be a step in the right direction. The problem of liquid waste is not this simple, as most farmers will not haul water to get a little fertilizer.

In this session, I will try to give you some of the concepts and basic ideas of how to utilize the liquid runoff from a feedlot in a profitable manner. At least we hope it can be profitable for some operation. We will also discuss how to utilize dry waste, how much can be spread on an acre of land, and how much it is worth in terms of commercial fertilizer.

Once the operator and designer of a feedlot have decided to dispose of the liquid waste material from the lot by applying it on agricultural land, there are several items they need to investigate before trying to design such a system for liquid waste.

I will try in a few minutes to make crop fertility, soils and irrigation experts out of you. At least, I hope to give you enough information to be able to discuss these points with the experts in each field. This will allow you to modify the information from this seminar to fit each feedlot in question.

The most important factor is how much land is needed, and what crops are going to be grown on this land. You will most likely want to grow a high volume crop such as a forage crop or a pasture crop. Crops such as these will remove large amounts of nutrients from the soil, therefore, you can apply more nutrients to each acre of soil.

Since the most urgent problem is liquid waste, we will want to consider irrigation as a means of disposing of liquid waste and growing crops.

When we speak of crop fertility, let us concern ourselves with forage--corn and sorghum, grain--corn and sorghum and pastures--wheat and grass.

The fertility needs of these crops can be seen in Table 1. We must keep these figures in mind at all times, since when we apply fertilizer to a crop with this disposal system, we can get too much of any one element on the land. In many cases, an excess of nutrients can have a toxic effect on plants. We must work out a system where we apply enough fertility for the plant with waste, and balance this with commercial fertilizer, if necessary.

The irrigation needs of these crops can be seen in figures 1 through 5 (corn-1, sorghum-2, wheat-3, tame grass-4, and sorghum and wheat-5.) These maps indicate how much irrigation water is needed to produce a crop in most years. This shows that in the western part, these crops will use as much extra water as they receive in yearly rainfall. The most important factor in water use, is the daily use or monthly use of the crop. As can be seen from figures 6-7, we can determine the total water used each month and subtract rainfall from this to predict how much water we can dispose of in any month. The peak use of most of these crops is about .3 inches per day. An irrigation system should be able to deliver this amount of water.

The water-holding capacity of a soil is very important in designing an irrigation system or a disposal field. Figure 8 shows the amount of water per foot that a soil might hold. As you can see, this will vary from 2 inches to less than 1 inch per foot. It should be pointed out that the plant can use only about 50% of this water without causing damage to the plant. Therefore, we can only apply enough water to replace what the plant has used. If we add more than the crop has used, we will drive water below the root zone and to a position where it will eventually end up in the ground water and cause pollution of the ground water.

The root zones of various crops are shown in figure 9. This gives us a clue as to how much soil we have to work with for any crop, relating this to the soil type we have to work with, will tell us how much water we can apply to the soil at any one time.

Once we get the factors of crop fertility, water use of a crop, water-holding capacity of soil and crop root zone depth well in mind, we are ready to apply this knowledge to a design for use of liquid waste.

It has already been pointed out at this meeting, that we can expect the dry material to contain 15 pounds of N, 9 pounds P_2O_5, 11 pounds K_2O plus other elements per ton. The liquid waste will contain from 135 to 1485 pounds of N with the average being 500 pounds, 70 pounds P_2O_5, and 380 pounds K_2O per acre foot. The nutrients contained in either the liquid or dry waste are not totally available each year. Many experts feel that only about 50% of the total is available the first year. The second year, only about 50% of the carry-over will be available. With the fact in mind that not all the nutrient is used each year, you can understand how the fertility level for the crop can be maintained with chemical fertilizers.

The first step in designing a disposal system is to decide how much liquid will be generated by the lot. This is determined by the rainfall patterns at the location of the lot. The runoff from feedlots at several points in Kansas has been studied in a report by Fred Bergsrud. These values are shown in figures 10 and 11. In designing the system at Pratt, we decided to use 14 inches of runoff as a maximum valve. This exceeds the 12 inches at a 20% chance. Using this figure, we would use about one acre of land for one acre of feedlot. When you get into an area of higher rainfall, you may need to use two or three acres of land for each acre of lot.

You may ask, "What about excess plant nutrients when we apply 12" per acre?" The answer to this is that we will not be applying this much waste in 8 out of 10 years. It appears from the amount of NPK in the waste, that we should consider using about 6" of liquid waste per acre of crop land. This would be an average year.

The problem of how to figure the acreage need for the disposal can be easily figured, but it takes time and could lend itself to a computer program. If you would take the 14 inches of runoff (1920) we used at the Pratt Feedlot, you will see from the following example how the system would work.

(See tabulation next page

Date	Rainfall	Feedlot Runoff	Effective Crop Rainfall	Crop Use	Pit Storage	Water In Soil
						Start 10:00
January	0.19	0.00	0.00	2.00		8.00
February	0.35	0.10	0.15	2.00	.10	6.15
March	1.00	0.55	0.60	3.00	.65	3.75
	Pump pit dry -- add 3" fresh water (pre-irrigate)					7.40
April	2.26	0.80	1.00	1.00	.80	7.40
May	4.19	1.62	3.00	4.50	.00	5.90
	During May pump pit dry -- no fresh water					8.32
June	2.76	1.00	2.00	6.50	.00	3.82
	Pump pit dry and add 5' fresh water					9.82
July	3.59	1.62	2.90	6.50	.00	6.22
	Pump pit dry and add 2" fresh water					9.84
August	5.25	3.13	4.00	6.50		7.34
	Pump pit dry					10.47
September	3.11	1.37	2.30	5.00		7.77
	Pump pit dry					9.14
October	4.28	3.00	2.00	3.00		8.14
	(One rain 3.51" field runoff of 2.00") Pump pit dry					11.14
November	1.86	0.58	1.30	2.00		10.44
	Pump pit dry					11.02
December	1.30	0.56	.95	1.00		10.97
	Pump pit dry					11.53
Total	30.14	14.33	20.20	43.00		
	Irrigation water add 10.00"					

As you can see from the above data, we were able to use the 14 inches of runoff on one acre of land without any real problems. We would have applied about 588 pounds of , 93 pounds of P_2O_5, and 448 pounds of K_2O to one acre of land. We must remember that on about 1/2 of this is available.

If we were growing a forage corn during the summer, and wheat pasture during the winter, we would have used 250 pounds of N, 90 pounds of P_2O_5, and 225 pounds of K_2O i the crops. If I had been running this system, I would have applied 100 pounds of N ...

20 pounds of P_2O_5 at planting time. The following year I would not apply any fertilizer early in the year.

You can see from this example that an average of 6 to 8 inches of runoff would not cause any problems in fertility or water use.

When you consider the fresh water supply need for a project of this kind, you should consider this as an irrigation project. Figure 12 shows you how much water is needed for the number of acres irrigated. The reason for using this amount of water is that you will be trying to grow a crop planted for irrigated conditions, and you must be able to supply it water during the stress period for the crop. This stress period will usually come at a time when you have no water from the feedlot runoff.

The storage that is provided for runoff from the lots should be more than the minimum required. I would like to see an extra 50% more storage built into each project. This would enable the operator to carry over and manage the runoff in a manner that it can be used by the crops.

We should build at least enough storage to be able to blend the waste water in equal parts with fresh water when we are using waste water. The situation will occur when it is necessary to use only waste water. When this happens, I would hope that we could limit our application rate from 2 to 4 inches. Here we are trying to apply small amounts of plant nutrients at any one time. When we have to go through a season using only waste water, we will have to balance our fertility program for the next year with what will be carried over from the last season. When a program of this nature is followed, we will lessen the risk of ground water contamination.

The blending of waste water with fresh water might be accomplished in a pipeline, but I have chosen to use a small pit for blending.

The equipment used to transport waste water will vary with the personal preference of the design engineer. However, there are several items which should be considered in selecting this equipment.

The pumps selected should be of the chopper type, or they should at least be able to discharge any material that can enter the intake side of the pump. These pumps should be as corrosion proof as possible.

The valves used on a project of this type do not need to be costly. There are many irrigation type flap valves which will work very well in most cases. The valves should be located above ground or in an area where they can be serviced easily. The check valve used on the fresh water supply must meet the standards for the city water supply. It must not leak any of the waste water back into the well.

When we discuss pipelines to move waste water from the pits to the irrigation fields, we should consider underground pipe. I would suggest using either plastic or asbestos-cement, since both of these will not be affected by corrosion from waste.

Since most of these systems will be low pressure, gravity irrigation systems, we can use low head pipe which is considerably less expensive than high pressure, water main pipe.

Once we have the water delivered to the filed, we should consider using gated pipe to control the release of this water to the crop. We know that the waste water will be harmful to the aluminum pipe and the gates. However, we do not know how long this pipe will stand up under these conditions, but I suggest that all pipes be flushed with fresh water after each use period. This procedure should prolong the life of the pipes.

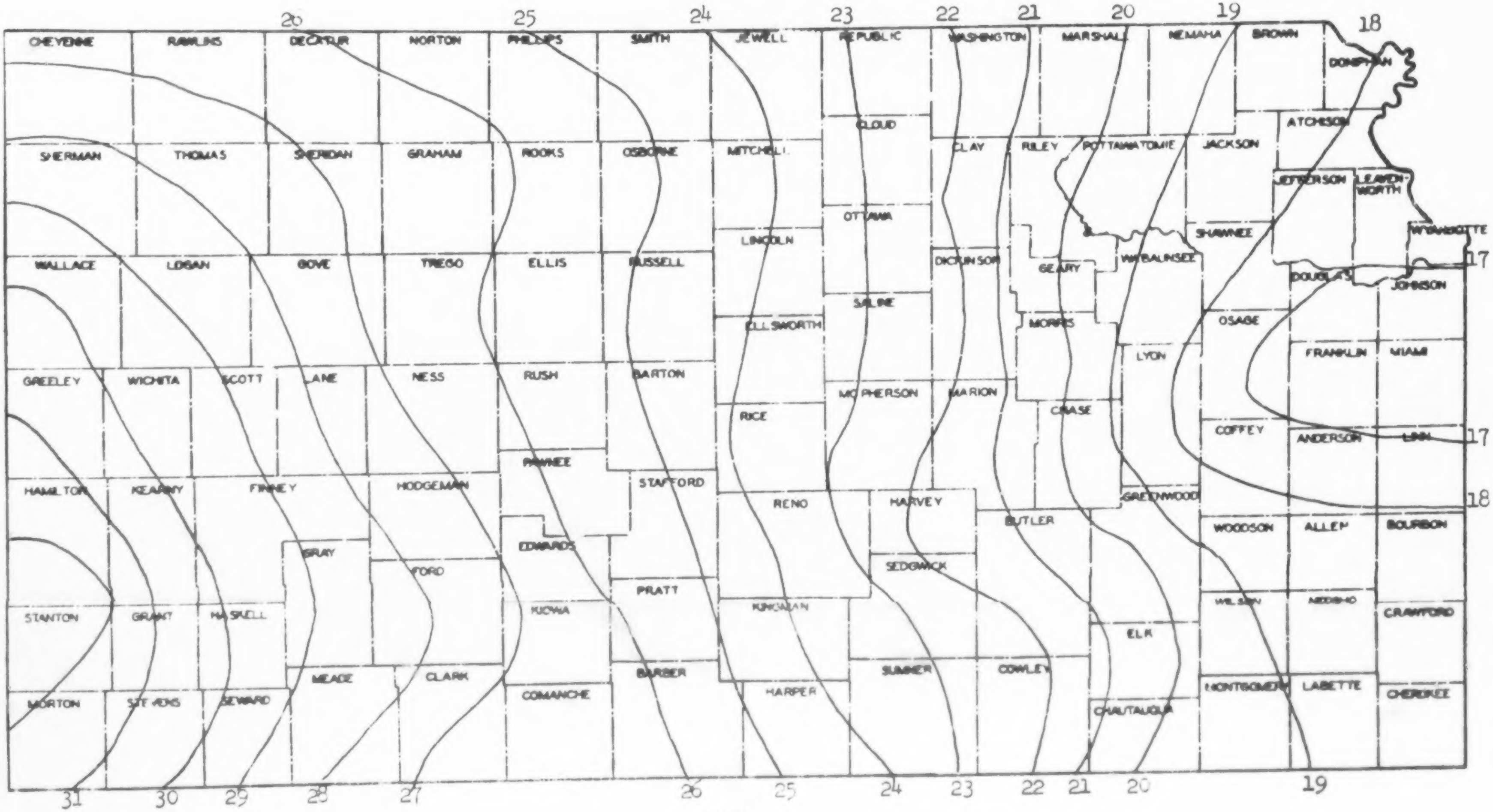
Each field or system must have a tailwater recovery system built into it. The tailwater recovery system will trap any waste water which is allowed to run off of the irrigation field. The tailwater system should be equipped with an automatic pump which will return the tailwater, either back to the head end of the field or back to the feedlot runoff pits. The pump for this system should be sized to return 20% of the flow delivered to the field. If 1000 GPM is delivered, then we need 200 GPM returned. The pump should also be manually controlled to allow them to be shut off when the irrigation system is not in operation. The pits or pumps used for the tailwater system should be constructed to allow storm runoff water to by-pass them.

Dry waste from feedlots may be more of a problem than liquid waste. Dry waste will contain only about 15 pounds of N, 9 pounds of P_2O_5, and 11 pounds of K_2O per ton. If you were to buy this as commercial fertilizer, it would cost about $3.00 per ton.

It would appear that you can apply 20 tons per acre yearly, if it is incorporated well and irrigation is used. There are areas in Kansas where 50 tons per acre were used for the last two years. I feel that this amount might be used for a few years, but should not be a regular program until we know more about this system.

Nutrient Needs of Crops (Table 1)

Crop	N	P_2O_5	K_2O
Corn, 120 bu.	180#	70#	140#
Corn, Forage	180	70	180
Sorghum, Forage	160	70	180
Sorghum, Grain	145	50	110
Wheat	70	20	25
Grass	160	70	120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CORN

Irrigation Water Requirements

Unit Values in Inches

(Based on 80% Precipitation Chance and 65% Irrigation Efficiency)

Figure 1

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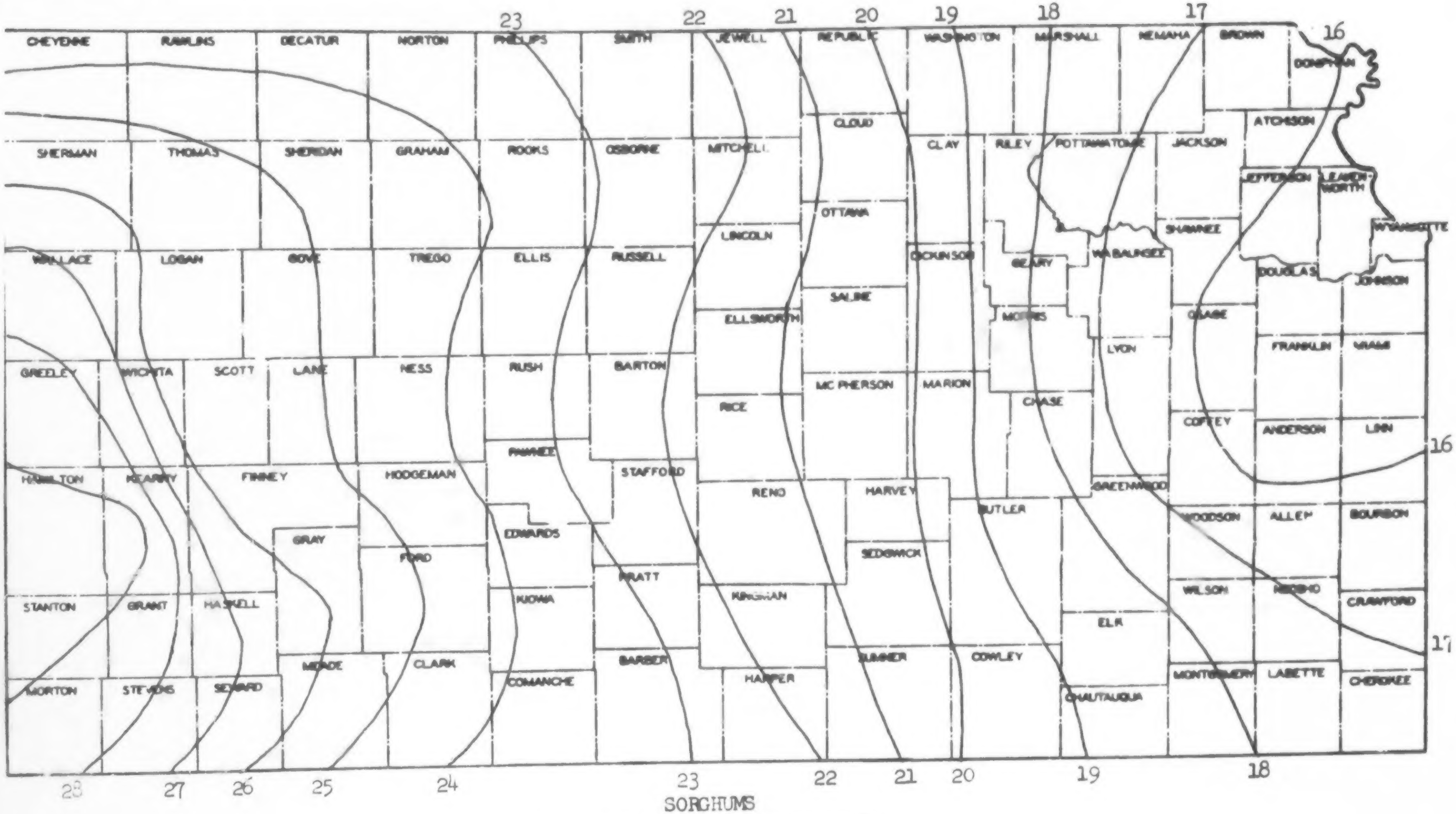
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SORGHUMS
Irrigation Water Requirements
Unit Values in Inches
(Based on 80% Precipitation Chance and 65% Irrigation Efficiency)

Figure 2

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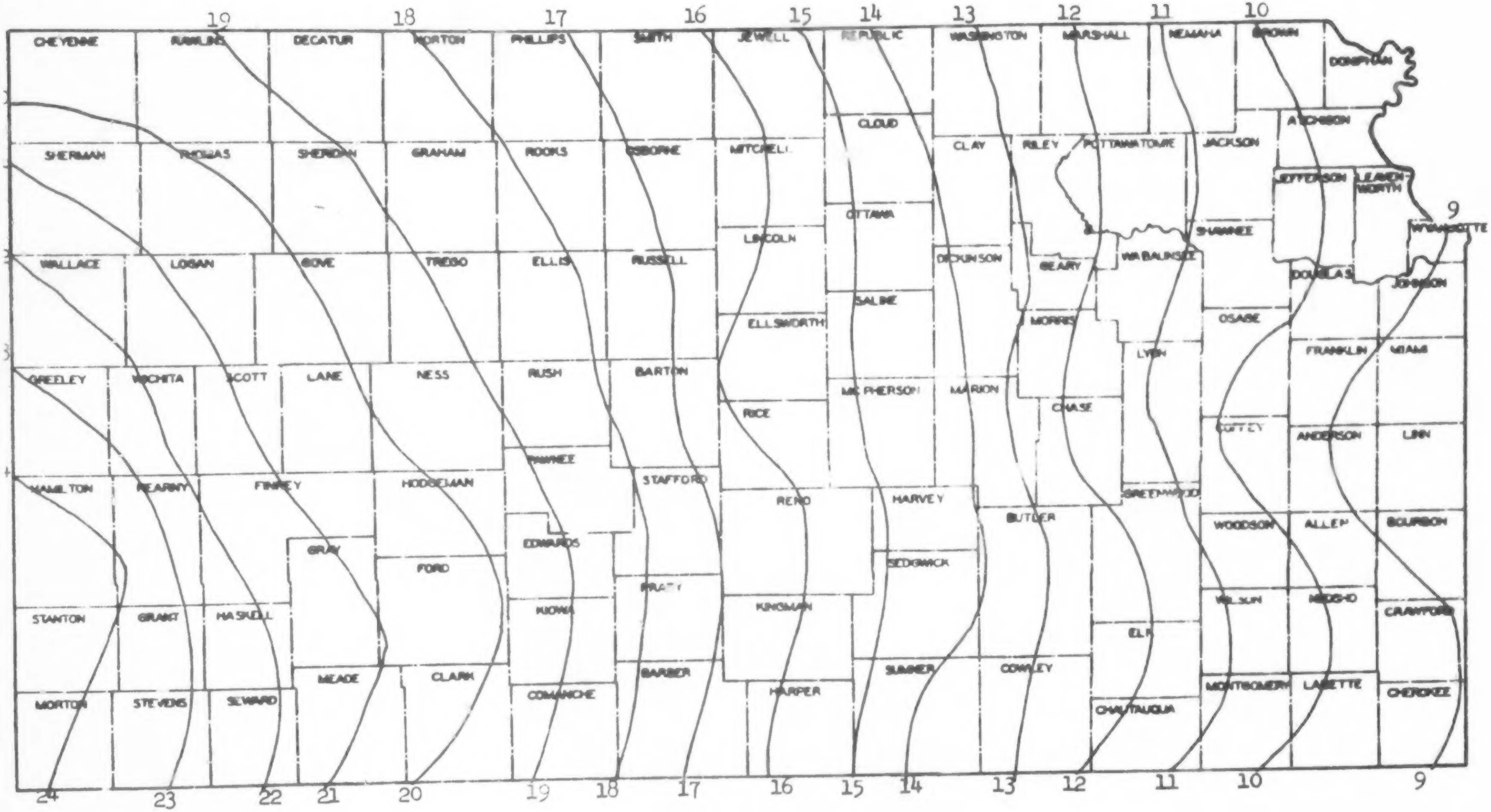
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WHEAT
Irrigation Water Requirements
Unit Values in Inches
(Based on 80% Precipitation Chance & 65% Irrigation Efficiency)

Figure 3

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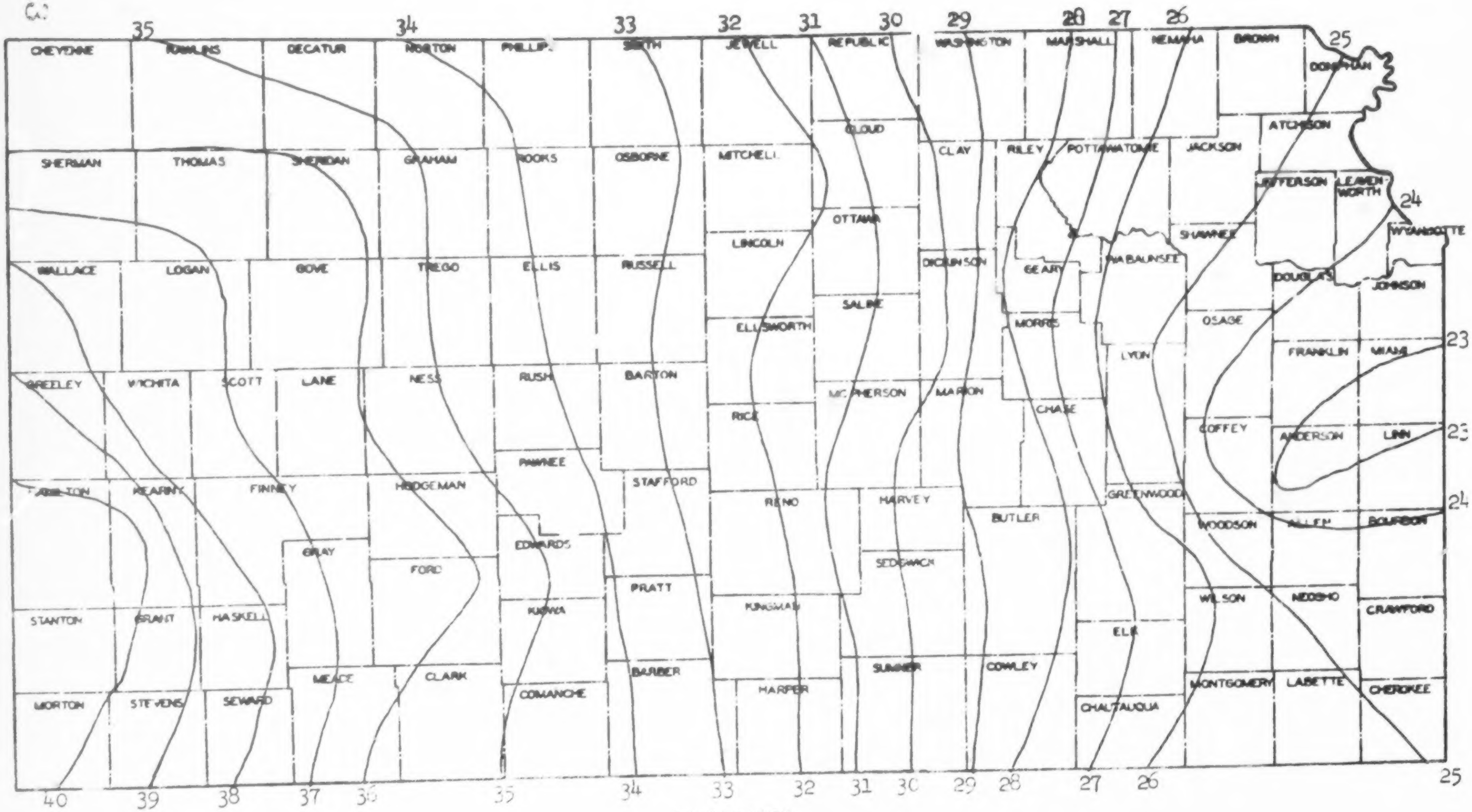
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TAME GRASS
Irrigation Water Requirements
Unit Values in Inches
(Based on 50% Precipitation Chance and 65% Irrigation Efficiency)

Figure 4

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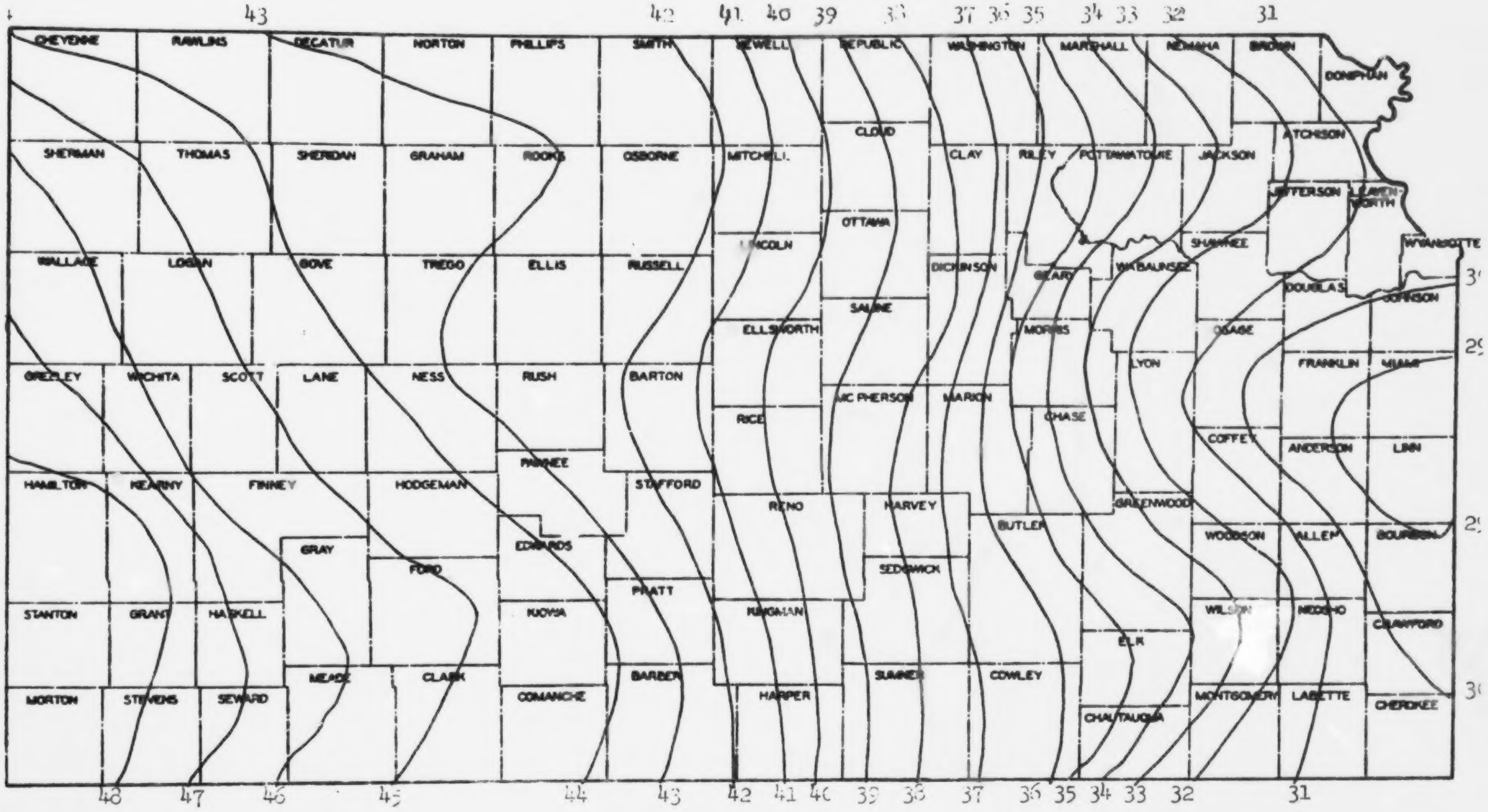
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DOUBLE CROP - SORGHUMS & WHEAT
Irrigation Water Requirements
Unit Values in Inches
(Based on 80% Precipitation Chance & 65% Irrigation Efficiency)

Figure 5

2a-050-5-3M

Daily Water Use of Crops (Figure 6)

Crops	June	July	Aug.	Sept.
	Inches per day			
Alfalfa	.30	.32	.30	.24
Corn	.07	.31	.33	.15
Sorghums	.07	.24	.29	.10
Pasture	.26	.29	.27	.21
Wheat	.26	.00	.00	.00

Total Consumptive Use of Crops (Figure 7)

Crops	Consumptive Use (inches)
Alfalfa	29 - 37
Corn	24 - 27
Sorghums	20 - 23
Pasture	25 - 32
Wheat (winter use)	13 - 17

Water Holding Capacity of Soils (Figure 8)

Texture	Inches per Foot
Very light, coarse sand	.75
Fine sand	1.25
Silt loam	2.00
Heavy clay loam	2.20
Heavy clay	2.00

Root Zones of Crops (Figure 9)

Crop	Depth (feet)
Alfalfa	6 - 8
Corn	4 - 6
Sorghums	4 - 6
Pasture	3 - 5
Wheat	4 - 6

Eighty percent chance occurrence runoff in inches interpolated from station data.

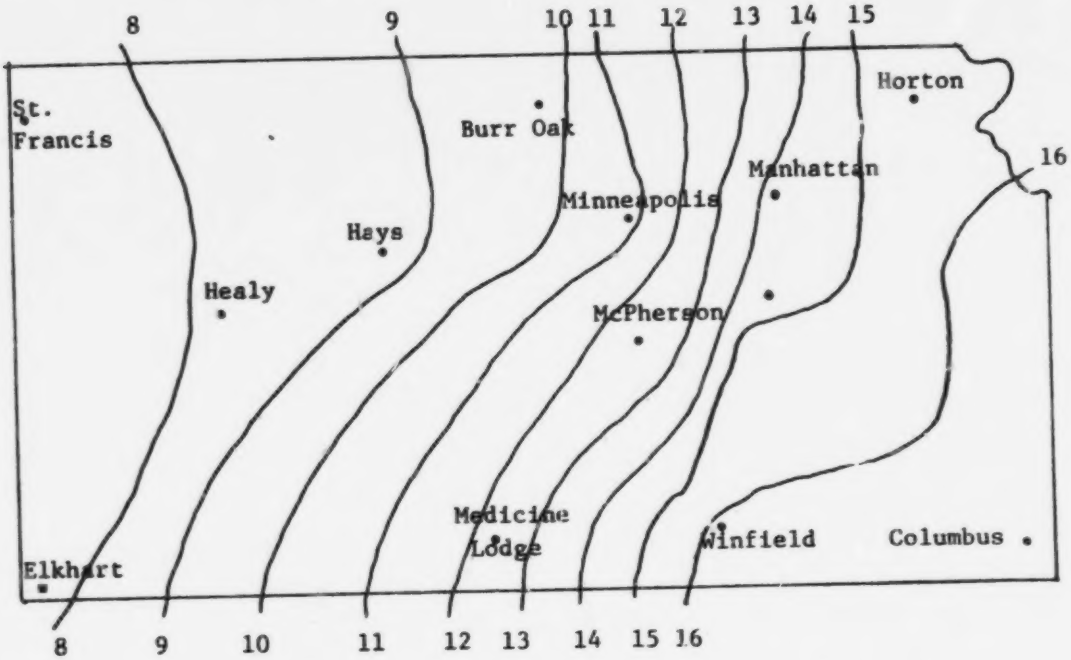
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Figure 10

Normal annual runoff in inches interpolated from station data.

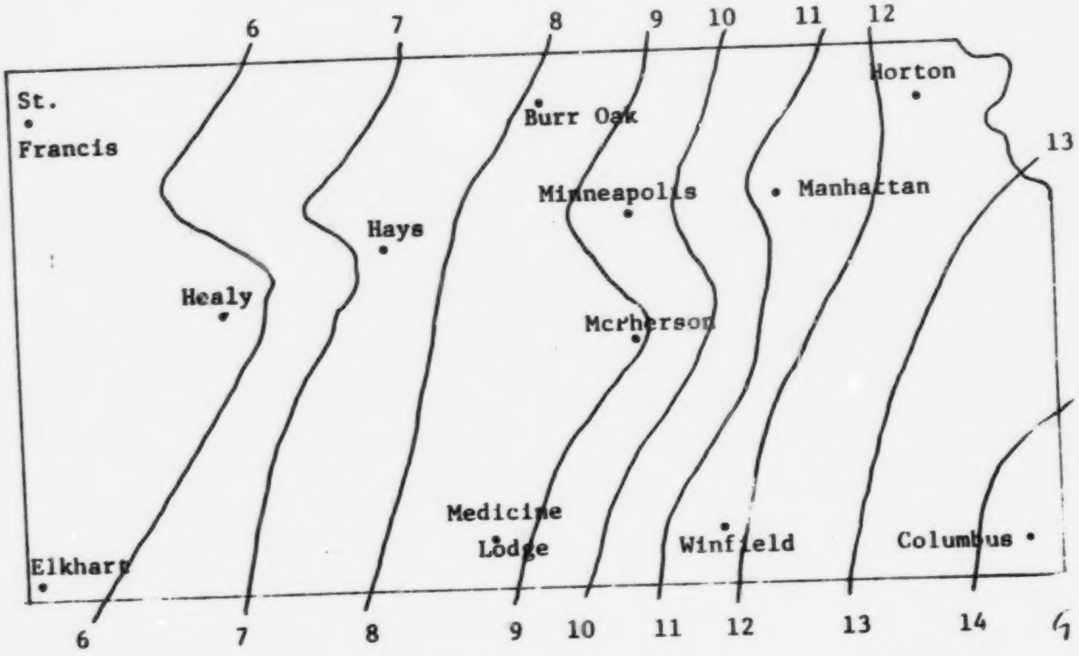
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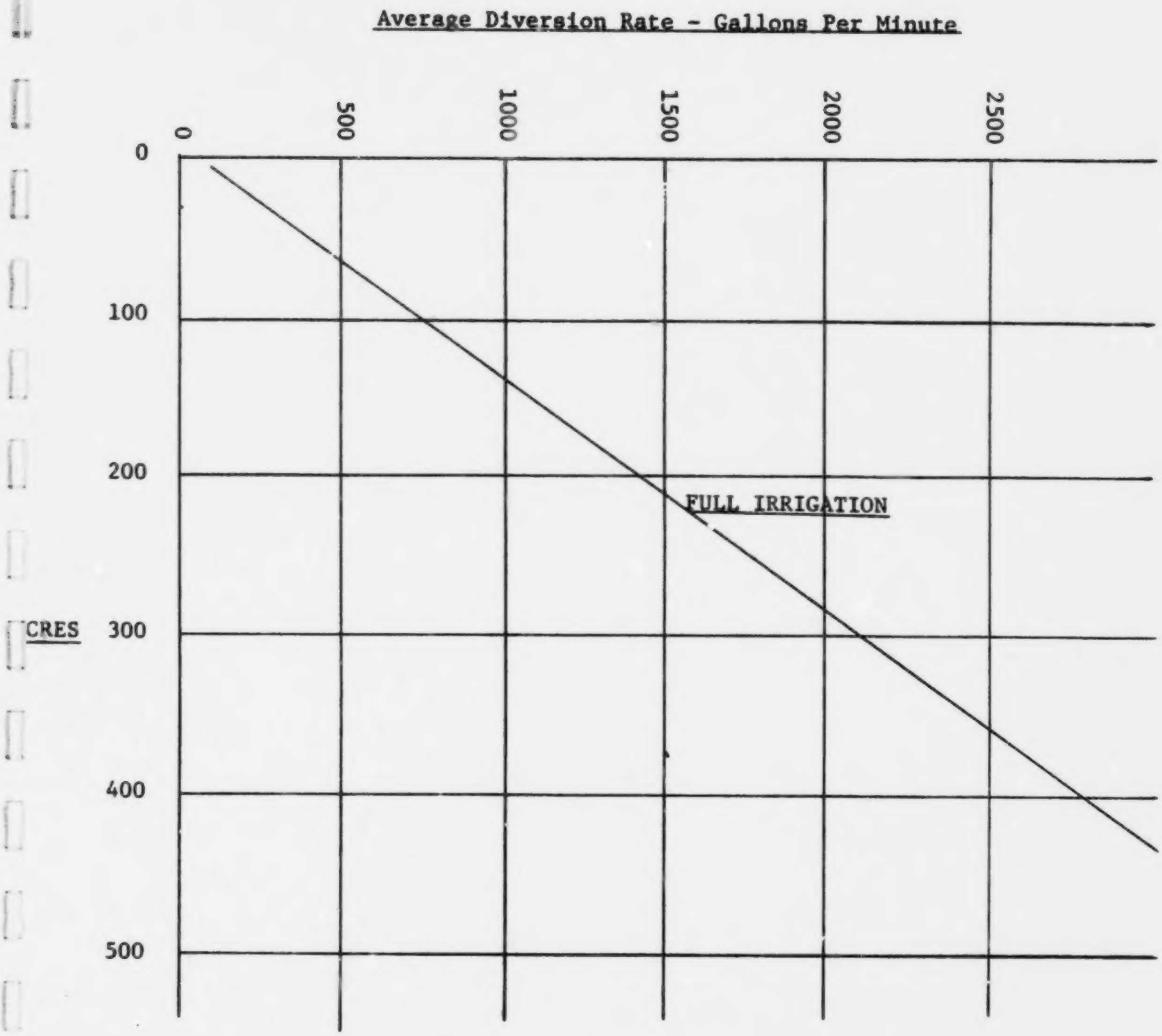
Figure 11



Method for Determining Acres to be Irrigated Annually
Based on Average Diversion Rate

Figure 12

DESIGN FOR FEEDLOT WASTE MANAGEMENT

History and Characteristics

R. I. Lipper, Associate Professor
Department of Agricultural Engineering
Kansas State University

The reason this seminar is being held is that the cattle feeding industry in Kansas has undergone vast changes in the past ten years. The trend established by these changes appears likely to continue into the future. And these changes have posed some new problems in preserving the quality of our environment.

Some of our people have reacted to the problems by advocating that the cattle feeding industry be throttled. This is not the way we have reacted to other problems associated with industrial expansion. It is my purpose to illustrate the value of this industry to the state of Kansas; to relate its growth in the state to the emergence of a water pollution problem; and to make an attempt to describe the nature and magnitude of the problem in the best perspective we can achieve at this time.

Americans are beef eaters and Kansas has the opportunity to supply a significant share of the demand. The United States per capita consumption of poultry and meat increased by about one-fourth since World War II while that of beef increased about 40%. Until the mid-fifties, the beef consumption cycle ranged from 56 to 65 pounds per person. It then broke out of the pattern. It has climbed to about 107 pounds and has not yet reached the top. Herrell De Graff, President of the American Meat Institute recently predicted a per capita annual consumption of 130 pounds in 1980. Some of the beef producers are talking about 200 pounds. Even at present consumption rates (and slaughter weights) each additional million people will require another 172,000 beef cattle.

The problem we are discussing relates only to the cattle that are finish-fed for slaughter. Animals go into feedlots weighing 600 to 800 pounds and are fed a ration

DESIGN FOR FEEDLOT WASTE MANAGEMENT

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The reason this seminar is being held is that the cattle feeding industry in Kansas has undergone vast changes in the past ten years. The trend established by these changes appears likely to continue into the future. And these changes have posed some new problems in preserving the quality of our environment.

Some of our people have reacted to the problems by advocating that the cattle feeding industry be throttled. This is not the way we have reacted to other problems associated with industrial expansion. It is my purpose to illustrate the value of this industry to the state of Kansas; to relate its growth in the state to the emergence of a water pollution problem; and to make an attempt to describe the nature and magnitude of the problem in the best perspective we can achieve at this time.

Americans are beef eaters and Kansas has the opportunity to supply a significant share of the demand. The United States per capita consumption of poultry and meat increased by about one-fourth since World War II while that of beef increased about 40%. Until the mid-fifties, the beef consumption cycle ranged from 56 to 65 pounds per person. It then broke out of the pattern. It has climbed to about 107 pounds and has not yet reached the top. Herrell De Graff, President of the American Meat Institute recently predicted a per capita annual consumption of 130 pounds in 1980. Some of the beef producers are talking about 200 pounds. Even at present consumption rates (and slaughter weights) each additional million people will require another 172,000 beef cattle.

The problem we are discussing relates only to the cattle that are finish-fed for slaughter. Animals go into feedlots weighing 600 to 800 pounds and are fed a ration high in grain and protein concentrate for about four months. They gain 2 to 3 pounds per day. Most cattle slaughtered in this country go through feedlots to meet the market demand for quality. About 2/3 go through feedlots now as compared to 1/3 before World War II. Production of fed beef now is nearly four times that of the 1940's and accounts for nearly all the increase in beef production.

There are over 10 million head of cattle on feed for slaughter in the nation. About 5 percent of the total are in Kansas but our share is increasing. Finish-feeding of cattle has grown more than twice as fast in Kansas than it has in the nation during the past decade. A study by the USDA Economic Research Service shows that fed cattle marketings in Kansas and Nebraska have increased an average of 12 percent a year between 1955 and 1967. The current annual rate of expansion in western Kansas probably is well in excess of 20 percent. Kansas presently ranks sixth among the states in the number of cattle on feed. Iowa still is No. 1 with most of its cattle in small farm feedlots. Nebraska is No. 2 and growing at about the same rate as Kansas. California, with an average of 1,800 head per feedlot is No. 3 but is slipping. Texas is fourth--Colorado fifth. The new glamour area for cattlemen is the Central Plains area including parts of Kansas, Nebraska, Colorado, and the panhandles of Oklahoma and Texas. This is the growth area for the large commercial feedlots. And these are the feedlots with the greatest need to control water pollution.

A recent survey (1968) by the Southwest Public Service Company of Amarillo, Texas, shows 274 large commercial feedlots in a 42 county area in Texas, Oklahoma, Kansas, and New Mexico. They have a total one-time capacity of over 1 million head--300,000 more than the year before and almost a half-million more than in 1966. It has been estimated that by the early 1970's, approximately 2,500 large commercial feedlots in the U. S wi supply nearly 70 percent of all the nation's finished cattle.

Kansas is in the forefront of the boom. In the past ten years the total cattle grain feed in the state has increased about 340 percent. Cattle in feedlots with over 1,000 head capacity have increased almost 770 percent. Ten years ago, about one-fourth of our fed cattle came from large feedlots--now it is well over half. There is a sound base for the expansion and it appears likely to continue. Western Kansas in particular has what seems to be an ideal combination of resources.

While the shift to fed beef was being made, it was discovered feedlots could be developed on a large scale, at a low cost, in arid areas. Feeders feel that cattle performance is better at higher elevations where summer nights are cool and humidity is low. The situation becomes almost ideal where irrigation is possible so forages and grain can be produced locally. These conditions led to rapid feedlot expansion in Colorado, California, and Arizona in the 1950's. California and Arizona were close to the highly concentrated, rapidly expanding, affluent beef-eating population centers of the West Coast. But with advances in meat packing and shipping efficiency, the cost of transporting beef to market is trending downward. Packing-houses are gaining more flexibility in choosing locations and are less concerned over having a source of finished cattle near big population centers. Since 1960, two major changes have accounted for rapid feedlot growth in Kansas, Colorado, and the Oklahoma and Texas Panhandles. These are the rapid growth of well irrigation and huge expansion in grain sorghum production. It is estimated that less than 30 percent of the sorghum now produced in the region is fed to cattle so there still is feed for further expansion. On top of this, it is the heart of the largest feeder calf producing area in the country. Nearly half the nation's beef cows are in a band running from the Gulf to the Canada line and extending from Missouri to the Continental Divide.

Large feedlots have a tremendous economic impact. Each animal requires 25 pounds feed per day--eighty percent of it grain. The cost of feeding including labor, taxes and other overhead runs about 60 to 65 cents a day per head in a typical operation on a year-around basis. Direct payrolls probably run about two men per 1,000 head capacity. Facilities require huge capital outlays for pens, drives, water systems, and sophisticated feeding and mixing equipment. The investment in a 10,000-head capacity feedlot is about 3 million dollars.

New capital is generated on many fronts ranging from irrigation equipment and farm machinery to packing plants. Dodge City today is moving more cattle than it did during the fabled days of Front Street when in 1884, 106 Texas longhorn herds came to Dodge City totaling more than 300,000 head. In 1967 the McKinley-Winter Livestock Commission Company sold 350,000 cattle worth more than 57 million dollars. The Dodge City Livestock Company added another 100,000 head. In a 46-county area, more than 3,200 applications for irrigation water wells have been filed with the state since 1962. Corn growing has moved into western Kansas where yields under irrigation are surpassing those in the corn belt in the northeastern part of the state. Sorghum production has boomed. New irrigated varieties give yields unheard of a few years ago.

Official conservative estimates of the dollar value of livestock in Kansas is 800 million. In reality it probably is closer to one billion. This is about matched by the value of the meat packing industry. Packing plants are moving out of the cities into the beef producing areas. Kansas plants slaughtered 1,617,000 head of cattle in 1967 which means that animals were brought in from out of state for processing in Kansas plants. New plants at Garden City and Liberal will ship out beef caracasses and keep much of the money at home. Iowa Beef Packers at Emporia is being expanded to replace the kill-and-chill operation with cut-and-fabricate. The new operation ships out boxed wholesale and retail cuts and requires major expansion for refrigerated cutting rooms.

Large-scale cattle feeding is a growth industry suited to Kansas resources and one that the state can ill afford to ignore.

It was a shock to livestock producers to find that their efficient production methods had given rise to a water pollution problem. The concentration of up to 200 animals per acre on areas ranging from 5 to well over 100 acres was quite a differen matter than having the wastes thinly scattered over many acres of grazing land. Every 900-pound steer daily defecates about 60 pounds of wet manure (43 pounds of feces and 17 pounds of urine) so each acre of feedlot is treated with about 6 tons of fresh manure every day. Since the land is exposed to rainfall, erosion and transport of the organic wastes is a natural result.

The State Department of Health started sampling streams below feedlots in 1963. Immediately after runoff occurred, they found high ammonia concentrations and zero dissolved oxygen extending for several miles in the receiving streams. Polluted slugs traveled downstream trapping fish and giving little warning to downstream users. Runoff from feedlots was blamed for killing over 2.6 million fish in Kansas in 1964, 1965, and 1966. Sometimes towns got into difficulty in treating the water for their use. Feedlots had come to be considered the most important uncontrolled source of stream pollution in the state.

Sportsmen and conservationists rallied to the cause. For lack of better information they sometimes used data on pollution by animals that failed to fit the context. Data can be found that shows the population equivalent of cattle wastes to be anywhere from 10 to 30 people. The most reliable current estimate places the value of the waste produced by one beef animal as being equivalent in five-day biological oxygen demand to that produced by 7.7 people. On that basis, if all the wastes from a 10,000-head feedlot were water carried as are most human wastes, a treatment plant like one for a city of 77,000 would be required. Fortunately, only a fraction of the organic wastes from feedlots is carried in the stormwater runoff.

Kansas State University used two small experimental feedlots to find the pollution potential of runoff. Precise data was not obtained because of the many variables involved but we have a much improved concept of the problem. Analysis of simulated and real stormwater runoff samples showed ammonia nitrogen concentrations ranging from 10 to 140 mg/l. Suspended solids varied from 1,500 to 12,000 mg/l. Chemical oxygen demand was 3,000 to 11,000 mg/l. The ratio of chemical oxygen demand to biological oxygen demand was 8.8 to 1. High concentrations of total coliforms, fecal coliforms, and streptococci were found. Pollutant concentrations were approximately twice as grea from a concrete lot as for an unsurfaced lot. Factors contributing to high concentrations were warm weather, low rainfall rates, and feedlot surfaces already wet before rainfall began. Doubling cattle population densities from 200 per acre to 400 per acre increased pollution potential by about 25 percent. Cleaning lots reduced pollution in the runoff for no more than two weeks following cleaning. Accumulating manure in packed mounds in the lots over extended periods had little if any effect on the nature of the runoff.

Avoiding muddy conditions in lots could be quite important. During a heavy rainstorm in late summer 1968, with lot surfaces wet when rain began, all pollution parameters greatly exceeded previously measured values. Three inches fell over a period of about eight hours. Suspended solids were 26,850 mg/l in samples taken 2.5 hours after the storm began and 45,200 mg/l an hour before it ended. COD exceeded 19,000 mg/l at both samplings. Manure had worked into a slurry by animals tramping and the prolonged rain. Similar conditions sometimes are encountered in commercial feedlots. Under such conditions, the large amount of suspended solids could cause excessive silting in pollution control structures.

Hydrologic observations were made to relate runoff rates to rainfall intensities. "Soil cover complex" numbers as used by the Soil Conservation Service appeared to adequately depict the relationship when values of 94 and 91 were used for the concrete lot and for the soil surfaced lot respectively.

Since the quality parameters of runoff were also related to rainfall intensities, it is possible, within broad limits, to estimate the total annual pollution loads generated by runoff from feedlots. These estimates, made with the aid of weather bureau records of rainfall, are lacking in precision but any estimates of pollution loads made on a per animal basis are meaningless in this context. Estimates made on a per acre basis using the type of data described offer a rational approach to showing the dimensions of the problem in a proper perspective.

The following example is an estimate made for the north central Kansas area where the average annual rainfall is about 30 inches. As a starting point, Table 1 shows the approximate amount of runoff from various size storms that might be expected from feedlots with surface characteristics similar to the Kansas test lots.

Table 1. Expected Runoff from Feedlots from Indicated Precipitation

Precipitation inches	Runoff inches	Runoff gal./acre
0.50	0.21	5,700
0.75	0.36	9,800
1.00	0.52	14,100
1.50	0.95	25,800
2.00	1.40	38,000
2.50	1.85	50,100
3.00	2.30	62,500

Table 2 is a hypothetical "average rainfall year," based on fifty-year data for north central Kansas.

Table 2. Average Number of Various Sized Rainfalls During the Four Seasons in North Central Kansas*

	Rainfall amount (inches)				
Season	0.01-0.25	0.25-0.5	0.5-1.0	1.0-1.5	1.5-2.0
Winter Dec., Jan., Feb.	10	2	1	0	0
Spring Mar., Apr., May	12	4	3	2	0
Summer June, July, Aug.	12	5	5	3	1
Fall Sept. Oct., Nov.	10	3	2	1	0

*Based on Kansas State Board of Agriculture data.

Table 3 combines the information in Tables 1 and 2 to predict feedlot runoff per acre during each season of the hypothetical year.

Table 3. Amount of Runoff Per Acre of Feedlot During Indicated Season

Season	Runoff*	
	inches	gal./acre
Winter	0.8	21,800
Spring	3.2	87,200
Summer	4.8	130,100
Fall	2.0	54,500
TOTAL	10.8	293,600

* Amounts and intensities of precipitation causing runoff were averages for fifty years.

Table 4 shows the BOD concentrations of the runoff during indicated seasons.

Table 4. BOD Concentrations in Cattle Feedlot Runoff During Indicated Seasons

	Concrete lot, mg/l	Soil surfaced lot, mg/l
Winter		
Typical concentration	450	250
Range	300-600	150-350
Spring and Fall		
Typical concentration	900	450
Range	750-1,050	350-550
Summer		
Typical concentration	1,300	680
Range	1,100-1,400	550-750

The data from Tables 3 and 4 used to calculate the typical annual BOD discharge per acre of feedlot, show 2,500 pounds of oxygen required to satisfy the demand of the annual runoff from an acre of concrete surfaced lot, or 1,200 pounds per acre of unsur faced lot. Sixty-two pounds of oxygen is the generally accepted amount required per year r person to stabilize domestic sewage. On that basis, the annual average human population equivalent of a one-acre, concrete feedlot is 40--or 20 with an unsurfaced lot. If the runoff from a feedlot were discharged uniformly each day, the estimated discharge om a 50 acre unsurfaced feedlot would be equivalent to the flow of untreated sewage from a community of 1,000 people. However, the storm water flow from the hypothetical edlot occurred only 30 days a year. On that basis average runoff on one of the 30 days was an organic load equivalent to the untreated sewage from 250 people. A 10,000-head feedlot on 50 acres on such a day would be equivalent to a community of 12,500 eople. But rainfall and runoff are seldom "average". In the sample area at least one two-inch rain can be expected each summer. The runoff from a 50 acre feedlot for such a torm would be roughly equivalent to a day's sewage flow from a city of 60,000 people.

Since it is expected that in many pollution control systems, runoff water will be aught in detention lagoons and later pumped onto cropland, its total nitrogen content ould be a useful parameter. Kjeldahl nitrogen concentrations in the Kansas State studies ranged from 50 to 500 mg/l. This is 11 to 122 pounds per acre-inch. The itrite and nitrate forms were low, ammonia and organic nitrogen being the principle forms. A good design value for nitrogen content is not available but about 40 pounds lemental N per acre-inch was estimated as a mean value for runoff from the University's est feedlots.

More information is needed on the concentration of salts in runoff water if it is to e used for irrigation. There is some indication of a possible hazard to soil structure because of the combined sodium, potassium, and ammonium ion concentrations. It is hoped hat more information on these properties will be available in the near future.

CONTRIBUTION OF FERTILIZERS TO WATER POLLUTION

G. E. Smith
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The use of chemical fertilizers has increased during the same period there has been development of public awareness of water pollution (16). A shift of an increasing population from rural to urban areas has created problems of both water quality and quantity in many areas. Chemical fertilizers have been essential to adequate food supplies. Crop production in the United States would probably be one-third less if chemical fertilizer use was at 1948 levels.

Recent legislation requires cities and industries to improve waste treatment facilities to reduce water pollution. Emphasis is being placed on water quality. Inference is made that where existing stream quality is above approved standards the quality will be maintained. Where chemical elements in water could originate either from metropolitan areas or from crop production; there is need to understand the soil reactions of these elements, the fate of chemical plant nutrients applied in fertilizers, and to determine the quantities that could enter surface and ground water.

More than 37 million tons of fertilizers were used in the United States in the year ending June 30, 1967. This is more than double the nearly 18 million tons used in 1948. In Missouri total tonnage increased from 355 thousand to over 1.3 million tons during the same period. Much of the fertilizer is now being used in the Missouri-Mississippi-Ohio River Basins. In 1967, Illinois, Iowa, Indiana, Ohio, Minnesota, and Missouri were all in the "top-ten" states in the amounts of nutrients applied from chemical fertilizers. (Other states in this group were: California, Texas, Georgia, and North Carolina.) Past concepts of using fertilizers only on low fertility soils have changed to application on those soils that have desirable terrain, the capacity to store rainfall - or where water for irrigation is available to produce high crop yields.

Most fertilizer is applied to supply nitrogen, phosphorus and potassium. The compounds that contain these elements also add other ions. However, to reduce freight and handling costs; the percentage of nitrogen, phosphorus, and potassium in fertilizer material is increasing. The total-average N-P_20_5 - K_20 contents of mixed fertilizers registered for sale in Missouri in 1948 was 21.4%. This figure had increased to 40.7% in 1963 and 44.1% in 1967. This trend to higher analysis is occurring in all states. While the total tonnage of all fertilizers used in the United States doubled between 1948 and 1967, nitrogen increased from 856 thousand to nearly 6 million tons; P_20_5 increased from 1.8 to 4.3 million tons; and K_20 consumption changed from less than one to more than 3.5 million tons. This trend to higher N, P and K content has eliminated some other elements formerly present as impurities that may be essential for plant growth. This has resulted in the increased use of trace or secondary elements for crop production on some soils.

A relatively few chemical compounds make up most fertilizer materials:

- Nitrogen - Anhydrous ammonia, either applied directly or as a base material for other nitrogen compounds, accounts for more than 90% of all nitrogen fertilizers in the United States. Nitrogen from the atmosphere is combined with hydrogen from natural gas. An increasing percentage of the nitrogen is applied to soil as NH_3. This gas is usually applied 6-9 inches below the surface. The NH_4^+ formed by the reaction of anhydrous ammonia with soil water is held by the negatively charged soil and little moves more than 4-5 inches from the point of release until the ammonia is converted to nitrate.

  Solid forms of nitrogen such as: ammonium nitrate; ammonium phosphates; and ammonium sulfate; are made by reacting ammonia with the respective acids. Urea is synthesised by reacting ammonia with carbon dixoide under suitable conditions.

  Nitrogen solutions are made from combinations of water with ammonia (aqua ammonia); or of urea and ammonium nitrate with aqua ammonia; or of anhydrous ammonia with ammonium nitrate. There is little difference in soil reactions whether nitrogen is applied to moist soil as a liquid or as solid prills.

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- **Phosphates** - Four phosphorus-containing compounds make up the bulk phosphates applied in crop production. (Higher plants can use only the ortho phosphate form.) Mono and di, calcium and ammonium phosphates account for most of the phosphates in fertilizers. The superphosphates contain phosphorus largely as mono-calcium phosphate. Complete mixed fertilizers will contain mixtures of mono and di calcium phosphate with some ammonium phosphates. As the trend to higher analysis continues, more phosphoric acid is being used in manufacture and the proportion of ammonium phosphates is increasing.

  Missouri and Illinois apply considerable tonnage of ground phosphate rock. This is a low solubility tri-calcium phosphate that usually contains about 30 percent total P_2O_5 and from 3-4% fluorine (apatite.)

  Small amounts of phosphoric acid are applied in some western states where soils are alkaline.

- **Potassium** - Probably more than 95% of the potash salts used as fertilizers are applied as muriate of potash containing 95-99% KCl. For some specialty crops such as: tobacco, grapes, and potatoes; potassium sulfate may be substituted for the chloride. For soils that may be deficient in magnesium, a double salt of potassium-magnesium sulfate is promoted. However, the tonnage of these latter two materials used is relatively small.

Other materials:

- **Calcium** - Most calcium is supplied in ground limestone. Missouri applied nearly 4 million tons in 1967. In the western states, gypsum ($CaSO_4$) is added to aid in the removal of excess sodium. Some gypsum is added as an impurity in lower analysis fertilizers, but the quantity is declining as more ammonium phosphate is used. Gypsum is added to muddy ponds to flocculate suspended material.

- **Magnesium** - Most magnesium added to soils is in dolomitic limestone or in potassium-magnesium sulfate.

- **Chlorine** - Chloride is the anion that accompanies potassium in most fertilizers. There is some question that this element is essential for plant growth. Some experiments have shown toxicity of chloride to plants in excessive amounts. Potash fertilizers are frequently applied in the fall to permit time for the chloride ion to leach from the root zone.

- **Sulfate** - Sulfate may be added in gypsum or potassium sulfate. Sulfur shortages are causing shifts to alternate manufacturing processes and the amount in fertilizers is decreasing. Some soil areas will require sulfur additions for optimum plant growth.

- **Trace minerals** - These include boron, zinc, iron, copper, and manganese and are added to specific soils or crops to correct deficiences. The amount used per acre is small. Most of these ions are tightly held by the soil colloidal complex. Boron and zinc are the only elements in this group that have demonstrated need in Missouri.

Fertilizer Reactions in Soils

Most of the charges in soils that hold nutrients are on the colloidal fractions and are negative. Ions a in fertilizers with a positive charge such as ammonium, potassium, and magnesium are less mobile than a the anions such as nitrate, chloride, and sulfate. Phosphate is also an anion; but because of its rapid rea with calcium, iron, magnesium and aluminum to form insoluble compounds, it becomes immobile (20). (Because of this "fixation" soluble phosphate fertilizers are often applied in concentrated bands near seeds to increase the percentage absorption by plant roots).

TABLE 1--IONIC BONDING ENERGIES FOR VARIOUS IONS IN SOILS

(calories per mole)*

CATIONS		ANIONS	
H^+	1800	Cl^-	0
Na^+	800	NO_3^-	0
K^+	1200	$SO_4^=$	0-1000
NH_4^+	1200	$PO_4^{\equiv}$	1600 (calcarious soils)
Ca^{++}	2800	$PO_4^{\equiv}$	2000-3000 (non-calcarious soils).
Mg^{++}	2600		
Al^{+++}	4000		

$$\text{Bonding Energy} = 1364 \log \frac{\text{Total adsorbed}}{\text{Amount in solution phase}}$$

(1364 calories corresponds to ratio 1-10, solution to solid phase)
(2728 calories (2 x 1364) corresponds to ratio of 1-100)

Table 1 gives the relative energy of adsorption on colloidal surfaces of some of the more common elements found in agricultural soils. In addition to surface adsorption of the potassium and ammonium ions, they can also nter the expanded lattice of some clay minerals and become firmly fixed and removed from the biological system.

Nitrate is the ion required in plant nutrition that is the most mobile and is of primary concern in water ollution. Figure 1 shows the reactions that occur when protein material from humus or plant residues are ecomposed by soil organisms to form nitrates. These processes become more rapid above 60° F and are very slow below 50° F. The reactions are similar regardless of the source of the nitrogen. It is well documented (1)(2) that on sandy soils the nitrates may be lost from the plant root zone by leaching. Where soils ave a high clay content and become water-logged the nitrate may be reduced and lost back to the atmosphere as elemental nitrogen or as nitric oxide (24). (This reduction of nitrate under water-logged conditions is the reason for ammonium salts being used in the fertilization of rice).

Fertilization practices with nitrogen differ depending on soil properties and climatic conditions. Where water movement is slow all of the nitrogen may be applied before or at time of planting. On many open soils ne or more side dressings may be used. Growing roots are effective in reducing downward movement of itrates. Addition of nitrogen in the ammonium form can have only limited effects on leaching since much ammonia is converted to nitrate before it is taken up by plants. Probably more than 80% of nitrogen in plant proteins is absorbed from the soil as nitrates.

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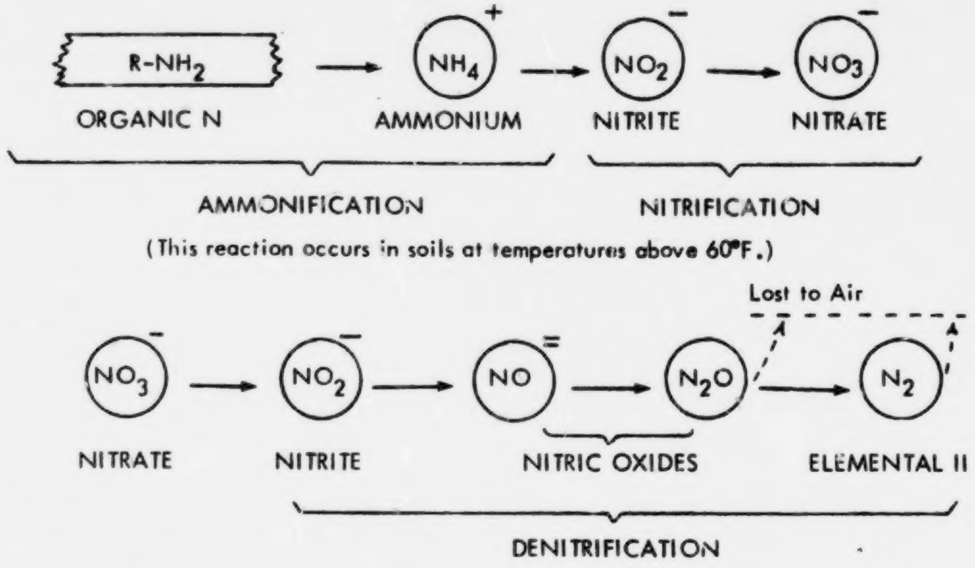

(This reaction occurs in soils at temperatures above 60°F.)

(This reaction occurs when soils are very wet)

Figure 1 - Soil reactions that occur when nitrogen is added to soil.

Methemoglobin and Eutrophication

Methemoglobinemia is a word coming into common usage by those concerned with high nitrate intake by livestock. (It is well known in the medical profession as a condition that can develop in infants caused by water high in nitrates.) Methemoglobin is the compound formed if nitrate (changed to nitrite) reacts with the blood to reduce the oxygen-carrying capacity. This can cause oxygen starvation (one cause of blue babies) or suffocatio in some animals. Public Health standards (6) list 45 parts per million of nitrate (10 ppm $N0_3$-N) as the amount that should not be exceeded in infant feeding. Many shallow wells in the midwest and western states have been found to contain nitrate in excess of this amount.

Eutrophication is the aging process where the addition of phosphate and nitrate to surface water will stimulate the growth of aquatic plants, and a bog or swamp will eventually result. The concentration of phosphate in the water is usually more critical than the nitrate in this process. Except in areas of very low fertility soils, drainage water will usually contain sufficient nitrogen to support the growth of algae.

Engineers responsible for providing potable water for domestic use are concerned about "nutrients" in water that stimulate this aquatic growth and refer to phosphates and nitrates. When the excess growth decays, oxygen is consumed and undesirable odors and flavors develop. The cost of water treatment for domestic use is increased and there is difficulty in maintaining quality. Also the growth may affect recreational uses of water and shorten the life of reservoirs.

The concentration of phosphorus in fresh water that will limit the growth of aquatic plants is about .02 ppm and for nitrate N it is from .05 to 1.0 ppm. The phosphorus content of sea water varies with location, but the average content has been estimated at about .07 ppm of phosphorus (3). An increasing and balanced exchange of nitrogen and phosphorus between organisms and their environment is essential for the continuity of life in the sea or in fresh water. Research workers in the field of aquatic biology refer to a ration of 1-8 for phosphorus and nitrogen in a living system as being important (21). When this ratio is below 8, phosphorus is relatively high. When the ratio is less than 8, more nitrogen is available than can be utilized and phosphorus is in short supply. In most instances a low level of phosphorus may limit aquatic growth more than the supply of nitrogen.

In areas of highly weathered soils, fertilizers high in phosphate may be added to ponds to stimulate the growth of fish food. However, in more fertile soil areas the drainage water from unfertilized land may contain sufficient nutrients to cause eutrophication. There is little data available on the amount of nitrate and phosphate in natural drainage water from productive soils that may have received no chemical treatment, but may have been growing legumes or receiving regular applications of farm manures. There can be little argument that liberal fertilization could contribute more of these nutrients.

Phosphate in the streams and the ocean is derived from mineral weathering and recycling the ions from previous organic assimilation. Rainfall contains sufficient nitrogen, largely as ammonium compounds, to be a factor in eutrophication. Near cities or in industrial areas, nitrogen in amounts of 30 or more pounds per acre in precipitation are common. This quantity declines in open country or in areas of low rainfall. From 7-10 pounds of total nitrogen per acre is frequently mentioned as the average for the entire country (8)(9). Most nitrogen would probably come down with the first portion of a rain. However, the quantity of nitrogen added on a national basis through rainfall would be a large amount and could be a contributing factor in eutrophication.

The amount of both nitrate and phosphate lost from agricultural land could be too small to be accurately measured by conventional chemical methods, but could be sufficient to influence the growth of some aquatic plants. The amount of fertilizer nutrients that will speed eutrophication presents distinctly different problems for agricultural interests than does the higher levels of nitrate that can be tolerated in water for animal or infant consumption.

Nutrient Losses in Leaching and Erosion

In irrigated sections of this country, water may be applied in excess to remove salts that are toxic to plant growth. Natural high concentrations of sodium and chloride are the ions of main concern. When this water leaves the land it will contain other elements, including nitrate and other mobile ions.

Stout and Burau (18) in California concluded that a major portion of the nitrate reaching underground aquifers was from urban areas and sewage fields. They further found that agricultural crops reduced the amount of nitrate in irrigation water that returned to lower soil depths.

In Missouri where precipitation exceeds evapo-transpiration, soils are acid in the surface. In this humid climate salts that weather from soil minerals are regularly leached and are a normal constituent of drainage water. Elements from land that can pollute streams are derived more from erosion sediments than from leachates. Losses of soil from agricultural land, highway construction, and from urban developments, are main sources of sediment that enter water courses.

Sediment is an important source of stream pollution. The type and vigor of cover on a watershed is a major factor to consider in determining the life of a reservoir. Losses of essential mineral nutrients during the past half century in the United States have been much greater from erosion than from crop removal. On low exchange capacity soils, leaching of nitrate can be serious. However, most soils in humid regions are so low in the other mobile anions (4) they can be disregarded as contaminants in percolating water. Phosphorus, potassium, calcium, magnesium, sulphur, and the trace elements are held by colloidal material--the particles removed in greatest quantity by erosion. Studies (5) of nutrients removed by erosion from three unfertilized midwestern soils, show losses several times greater than are removed by crops. Results obtained on a 3.6 Shelby loam are shown in Table 2. Most of these measurements were made prior to 1940 when little chemical fertilizers were used and farm manures or legumes were the source of added nutrients. Little information has been obtained on leaching losses under soil management practices with excessive fertilizer addition, but some data (22) is accumulating particularly on open soils, where percolation of the mobile anions (NO_3^-, Cl^-, and S may be greater in areas of high rainfall or with excessive irrigation, than had been expected. Losses of po-tively charged ions from soils with average clay content have apparently not increased more than enough to balance the negatively charged ions removed.

Also numerous measurements of leaching losses have been made by workers in different parts of the country using lysimeters. Kohnke, et. al (12) have reviewed work with lysimeters involving agricult and found calcium is the cation lost in largest amounts. Most nitrogen leached from soils was in the nitra

TABLE 2--ANNUAL NUTRIENT REMOVAL IN RUNOFF AND EROSION--SHELBY LOAM, 3.6% SLOPE, NO FERTILIZERS; POUNDS PER ACRE*

CROPPING SYSTEM	Total N	NO_3	P	Ca	S
Not cultivated	99	6.1	48	379	101
Spaded 8" deep	74	2.5	33	226	64
Bluegrass sod	.6	.3	.1	.6	
Wheat annually	30	1.4	11	76	19
Rotation - corn, wheat, clover	6	.8	2	41	7
Corn annually	40	1.0	8	103	25

* Adapted from F. Duley and M. Miller

form, and originated from decomposition of organic matter. The leaching of phosphate from agricultural lands was very small and the movement of other anions and cations was too small to have significant effects on the concentration in underground water supplies. Most of these measurements were made on soils receiving little chemical treatment and are of only limited value in supplying information on the downward movement of surface applied chemical soil amendments. Some work using the ceramic cup technique indicated that heavy field applications of ammonium nitrate may move beyond the root zone in greater amounts in clay soils than was formerly believed (23). Stallings (17) has pointed out the importance of vegetative cover in reducing soil and water losses. It is now being recognized that adequate soil fertility treatments* can provide adequate soil cover, reduce runoff and errosion, and reduce the quantity of fertilizer nutrients that could enter surface water supplies.

Soil analyses have been made on soil to a depth of 4 feet on Sanborn Field Plots (Missouri Agricultural Experiment Station) that have received chemical fertilizers annually since 1888. Results given in Table 3 show little difference in nitrate, phosphate, potassium, calcium, or magnesium at the lower depths, from other plots that have received little fertilization. There is a suggestion of greater calcium movement with higher fertilization.

TABLE 3--POUNDS PER ACRE OF NUTRIENT CONTENT OF THE 36-48 INCH DEPTH OF SANBORN FIELD PLOTS AFTER 75 YEARS OF CHEMICAL SOIL TREATMENTS

	Continuous wheat		Corn in rotation		
	No treatment	Full*	No treatment	Manure †	Full ‡
P_2O_5 (weak Bray)	35	25	147	90	25
P_2O_5 (strong Bray)	138	30	360	370	75
Potassium	155	94	410	205	147
Magnesium	855	850	850	960	[illegible]
Calcium	3990	4590	3450	3525	3800
pH, water	6.3	6.9	6.4	6.3	6.2
pH, salt	5.8	6.5	5.9	6.0	5.8
Ex. H, m.e./100 g	2.0	1.0	2.0	1.5	0.8
Organic matter, %	0.7	0.7	0.7	0.6	0.7

* N-P-K from inorganic salts applied annually in amounts removed in grain and straw of 40 bu/acre yield.

† Six tons barnyard annually.

‡ N-P-K from inorganic salts in amounts removed by crops (80 bu corn, 60 bu oats, 40 bu wheat, 3 tons clover and timothy, per acre 6 years' rotation).

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* Unpublished data of the author

Nitrate Studies of Water Supplies

Analyses of more than 6,000 water samples from rural Missouri collected since 1963 show that 42% contained more than 5 ppm NO_3-N. These studies indicate that animal wastes, improperly constructed shallow wells, and septic tank drainage are the main sources of this contamination (11)(15).

When livestock numbers by counties in Missouri (cattle and hogs) are correlated with nitrogen use an r value of +.75 is obtained. (Counties with the largest number of livestock use the most fertilizers.) The number of water supplies containing nitrate varied from a low of 12% to over 75% in individual counties. In some counties in the northwestern part of the state where the deeper aquifers contain a high salt content, and shallow wells are the only ones available, over 50% of the wells sampled contained sufficient nitrate to be of concern in livestock production. In many cases the yield of water is so low, little casing is done so a maximum amount is obtained from the near-surface layers.

There was a definite statistical relationship between livestock numbers and shallow wells containing nitrate. Nitrites were found in only 1-2% of rural wells during the winter months but this increased to 3-4% in warm weather. Highest contamination was found in areas with the largest livestock production. There was good correlation between the nitrate content in well water and hydrologic-geologic areas, but only a limited relationship with soil types. The greatest number of water supplies with high nitrate (and nitrite) were in the northern part of the state where previous loess overlies low-permeability glacial clays, and where the water accumulates at the junction of these two materials. This area has been farmed for 75-100 years and livestock production is the main source of income. Many of the farm water supplies are located close to feed lots or silos. There is a high degree of correlation between the occurrence and concentration of nitrate in these wells and their proximity to livestock feeding areas.

Little correlation was found between use of nitrogen fertilizer (Figure 2) and high nitrate or nitrite in adjacent water supplies, except in some sandy alluvial soils of the Mississippi and Missouri flood-plains. In these soils where the water table is from 10-20 feet below the surface, the heavy use of chemical nitrogen appears to have been a factor in the nitrate found in some shallow wells. In areas of sandy alluvial soils, shallow wells (sand points) show a high nitrate contents when located within cattle or hog feeding operations.

In the level, heavily fertilized alluvial soils in Missouri, the concentration of nitrate is much lower in well water than in the loessial-glacial areas with dense livestock populations.

A number of shallow wells supplying small towns have been found to contain significant amounts of nitrate. In most cases the source of this nitrate could be traced to inadequate sewer systems, cesspools and lagoons contaminating the ground water.

The residual limestone area of south Missouri is largely in forest and unimproved pasture, and little chemical nitrogen fertilizer is used. Many large springs, caves and sink holes are found in this area. A nitrate-N content of 5-15 ppm in the spring water could be accounted for by natural soil leachate and/or bat guano in the caves.

For example, Big Spring in Carter County, has a maximum flow of over 800 million gallons of water daily. An average daily flow of 252 million gallons has been found over a 17-year period. Analyses of the water in 1964 showed a NO_3-N content of 2.4 to 3.0 ppm. Three ppm in 252 million gallons of water is over 6000 pounds of nitrogen. The drainage area of Big Spring has been estimated at 440 square miles. Assuming that one-fourth of the 48 inches of annual rainfall percolates through the soil, an average of 250 million gallons daily would be obtained. A discharge of 6,000 pounds of nitrogen daily would amount to less than 8 pounds of nitrogen per acre per year; a realistic leaching loss even on the low fertility forest soils of the area. Five or more pounds of nitrogen per acre probably is added to soils in precipitation each year. This regular addition of nitrogen in rainfall could account for most of the nitrate discharged by this spring. (On a state-wide basis an average of 5 pounds of nitrogen per acre annually on the 45 million acres would be more than 110,000 tons, or about one-half the amount sold in chemical fertilizers in Missouri last year.)

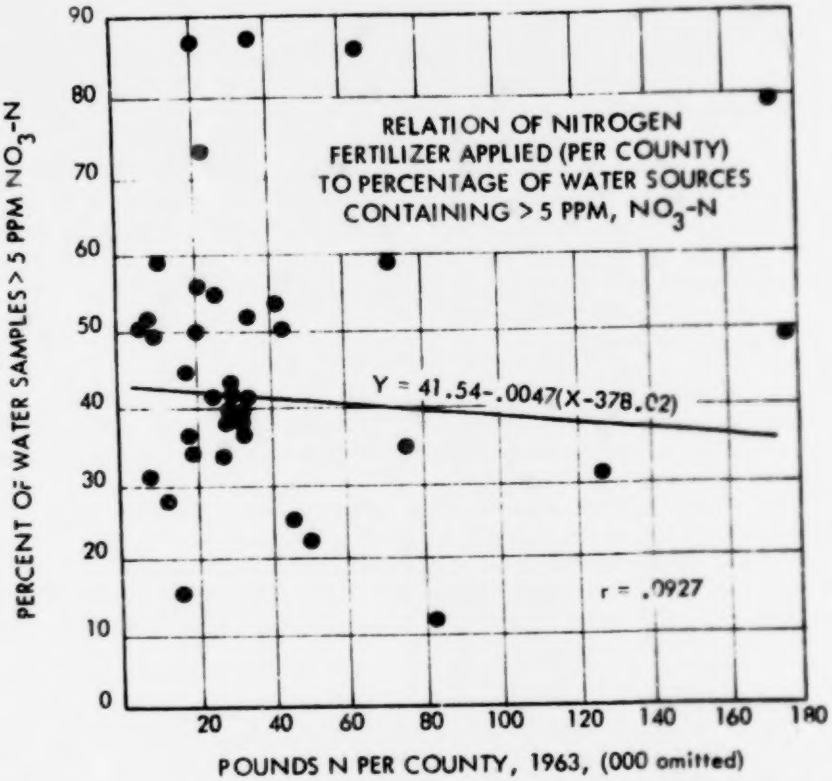

Figure 2 This Diagram Shows the Lack of Correlation Between the Amount of Nitrogen Fertilizer Used in Individual Missouri Counties and the Percentage of Wells Containing Over 5 PPM of Nitrate-Nitrogen

Many caves in Missouri (and in other parts of the United States) have been used in the past as sources of potassium nitrate for the manufacture of gunpowder. This caliche was secured as crystalline KNO_3 from walls and crevices (probably infiltrates and from leaching from bat guano deposits). About one-third of the 1450 known caves in Missouri contain bat guano. Good correlations have been obtained for nitrate in spring water flowing from caves and guano deposits. Watercress in water courses is an indicator of nitrates in water in south Missouri. Watercress has been analysed and found to contain from .25 to .96% nitrate-N (dry weight basis). Watercress has not been found in spring water discharge that does not contain nitrate at some season of the year.

Because of the highly fissured and cavernous nature of the soluble limestone-dolomite rocks in the Ozark Region, it is plausible that leachates from bat guano deposits could descend to deep aquifers and provide a high nitrate content in water from strata reached by deep wells that are improperly cased.

Numerous surface rural water supplies (ponds from 1/3 to 5 acres in size) were sampled. Few contained more than 0.5 to 0.75 ppm of nitrate nitrogen even though they received drainage from livestock areas. Although unconfirmed reports have been received of nitrogen fertilizers eroding into surface impoundments with heavy rains; no reservoirs were sampled in which fertilization of crops on the watershed with nitrogen caused increased concentration of nitrate in the water. Little correlation was found between nitrate concentration in water and a growth. This result would be expected, since any large amount of nitrate added to the water would probably be rapidly absorbed by the vegetation. An equilibrium would probably be reached where the aquatic plants would reduce both the concentration of both nitrate and phosphate in the water to some uniform level.

Soils Under Feed Lots Contain Nitrates

Soil cores to depths of 20-25 feet were taken in feed lot areas and near wells that showed high nitrate conent. Where livestock had been fed for more than 50 years, from 2,000 to 4,000 pounds of nitrate nitrogen per acre were frequently found. Many layers of soil under the feeding areas in some soils contained, at depths of -10 feet, 500 to 600 pounds of nitrate nitrogen per acre-foot. Interestingly, some of the deeper horizons conained very few bacteria. It is believed that where the subsoil was extremely low in organic matter there was little reduction of the nitrate, and it accumulated. In the Midwest, where summer droughts are frequent, soils crack to a considerable depth. When rains do come, they may be heavy and carry the nitrate to lower depths efore the soil fissures close from hydration and swelling.

Soil cores have also been taken in areas where feed lots were abandoned 5 to 15 years past, and (in some ases) where new lots were in the same area. This gave information on the residual effects of previous conamination. Generally there was a substantial drop in nitrate content of the surface 2-4 feet of soil on abandoned lots after a few years, but the nitrate persisted at the lower depths. A sufficient number of areas near wells high in nitrate were studied where no obvious source of contamination was evident. At some locations it was ossible to establish that nitrate was derived from some long abandoned privy or livestock feeding operation.

Lateral Movement of Nitrates

Deep soil cores have also been collected at various distances from concentrated livestock feeding areas, from septic tank tile fields, and below sewage lagoons; see Tables 4 and 5. Although the lateral movement of nitrates through the soil is influenced by soil texture, the concentration usually diminished 200 to 300 feet from he pollution area. Where sampling extended into liberally fertilized cropland the amount of nitrate found was nsignificant in comparison with that in the feeding pens or near the waste disposal systems.

TABLE 4--NITRATE NITROGEN CONTENT OF TWO SOILS AT VARYING DISTANCES FROM OLD FEEDLOTS

Distance from contaminated area, ft	FARM A *		FARM B †
	Pounds N/acre 0-18 ft	NO_3N in groundwater, ppm	Pounds N/acre 0-13 ft
0	2425	73	1375
150	1475	48	357
300	1014	13	317
600	780	Trace	275
5280	958	. . .	227

* Loess soil, level topography, approximately 80% silt.
† Silt loam, but with 25-40% clay below 24 in.

TABLE 5--NITRATE NITROGEN CONTENT OF SOIL AND GROUNDWATER AT VARYING DISTANCES FROM SEPTIC-TANK DRAINAGE FIELD
SALINE COUNTY, MISSOURI

Distance from septic tank, ft	Pounds N/acre 0-13 ft soil	N groun water, pp
60	474	[illegible]
86	375	[illegible]
112	308	[illegible]

Losses of Nitrate in Runoff Water

Measurements made of the nitrate content of runoff water from the Missouri Claypan Station, McCredie, erosion plots are shown in Table 6. Nitrogen lost from two rains during June of 1964 was very small. The loss was greater from unfertilized fallow plots than from liberally fertilized, continuous corn. It could be reasoned that except where severe storms immediately followed nitrogen application, little nitrate would move from fields. Nitrogen would not be applied by wheeled vehicles unless soils were below field capacity of moisture and initial rainfall would carry the nitrate below the land surface. Nitrogen would be applied only when soils are sufficiently dry to absorb initial precipitation. The mobile nitrate ion would be carried into the soil and only lost under conditions of severe erosion.

TABLE 6--NITRATE-N IN RUNOFF WATER FROM CORN,
McCREDIE, MISSOURI, JUNE 1964*

Cropping System	N-treatment	Ft^3 Runoff	NO_3^--N lost per A.
Fallow-clean tilled	None	140/acre	.8 lbs.
Corn-oats Rotation	None	1170	.3
Continuous Corn	9	64	.4
Continuous Corn	9	28	.09
	177	7	.01

*Total of two rains (4.5"), June 16 and 30

These results agree with other studies (19) and indicate that for most rains in the Midwest a very small percentage of fertilizer nitrogen applied to well managed soils is lost in runoff. A fertility program that provides a vigorous, dense cover could be effective in increasing transpiration and reducing runoff and sediment loss. Adequate soil fertility treatments are a most effective soil conservation practice.

Studies of Lake Mendota in Wisconsin (14) indicate that runoff from frozen fields, that had received application of farm manure, was the main source of nitrogen in the lake water from an agricultural source. Nitrogen in precipitation, urban runoff, domestic wastes, and nitrogen fixation by aquatic plants, made up most of the other nitrogen inputs. The possibility of runoff from frozen land could be sufficient reason for not applying manures or chemical fertilizers to frozen soil during winter months.

Residual Accumulation of Fertilizer Nitrogen

A major portion of the chemical nitrogen used in the Midwest is applied to corn. This crop grown annually in thicker stands, is replacing the old rotation systems. The amount of chemical nitrogen frequently applied may be above immediate crop needs. It is when rates of nitrogen application are in excess of crop removal there is concern of nitrate moving into groundwater.

Soil cores to depths of 10-20 feet have been collected from experimental plots where liberal nitrogen treatments (chemical N or farm manure) have been applied for years. On Sanborn Field (silt loam with claypan) where treatments have been made since 1889, the nitrogen treatments have had little effect on total N or nitrate N below the root zone. It is believed most nitrogen that cannot be accounted for in crop removal from these experimental areas has been lost by denitrification or by erosion.

Table 7 shows the quantity of nitrate nitrogen found in the surface 10 foot depth of a Mexico silt loam aft 20 years of continuous corn where 120 pounds of nitrogen have been applied annually.

TABLE 7--NITRATE NITROGEN IN PUTNAM SILT LOAM AFTER PRODUCING CONTINUOUS CORN FOR 20 YEARS AND RECEIVING 120 POUNDS OF NITROGEN (AMMONIUM NITRATE) PER ACRE ANNUALLY.

Depth, ft.	No Nitrogen	120 lb N/A Annually
	Pounds per Acre	
0-1	17	88
1-2	6	38
2-3	5	13
3-4	2	16
4-5	2	24
5-6	2	18
6-7	2	10
7-8	3	9
8-9	2	4
9-10	2	2
Total	42	222

These results (samples collected in February 1968) show 180 pounds more nitrate nitrogen in the surface) feet of soil where the 120 pounds of N had been applied annually for 20 years, than where the soil received no nitrogen. This is 9 pounds per acre per year. This is not a large amount, but assuming that a portion ould eventually enter water courses by seepage, this could be sufficient to stimulate plant growth in lakes or reams.

Nitrate movement has also been measured in complex nitrogen rate X corn population studies on soils widely different characteristics. The nitrate content of these soils shown in Figures 3, 4, and 5, were made after seven years of annual nitrogen treatments. The rainfall ranged from about 30 to nearly 50 inches each year, but varied with the season. No supplemental irrigation was used in these experiments. Yields of corn uctuated with location, season, and population, but ranged from low yields of about 60 to more than 150 bushel r acre. The effect of population on yields has varied with rainfall. It has been difficult to measure a relati ship between stalk count and nitrate accumulation. These results show that the more open the soils the great he downward movement of nitrates. Also there is a lower amount of residual nitrate in the sandy soil than in ose with a higher silt and clay content.

Under these Missouri conditions it appears (Figure 3) there has been little accumulation of nitrate when e annual rate of application of nitrogen is 100 pounds per acre or less. Where the treatment exceeded this mount (all rates not shown) the nitrate accumulation increased. On the sandy soil (the only location to receive a 300 pound rate of nitrogen) there was little difference in accumulation with 200 pounds or less per acre of trogen treatment. These results would suggest that to keep nitrate from leaching into groundwater the rate nitrogen treatment should be no higher than is required for optimum yields.

Some Conclusions

Prior to the last quarter century production of food crops in the Midwest depended on nitrogen from soil umus, from legumes (atmospheric fixation) and from animal manure. Phosphorus available to plants and othe inerals were the decomposition products of soil minerals. The productivity of land was largely determined the amount of nutrients present and availability of moisture to crops during the growing season. Within the pas 20-30 years nutrients supplied by the chemical industry (fertilizers) are substituting for the elements formerly

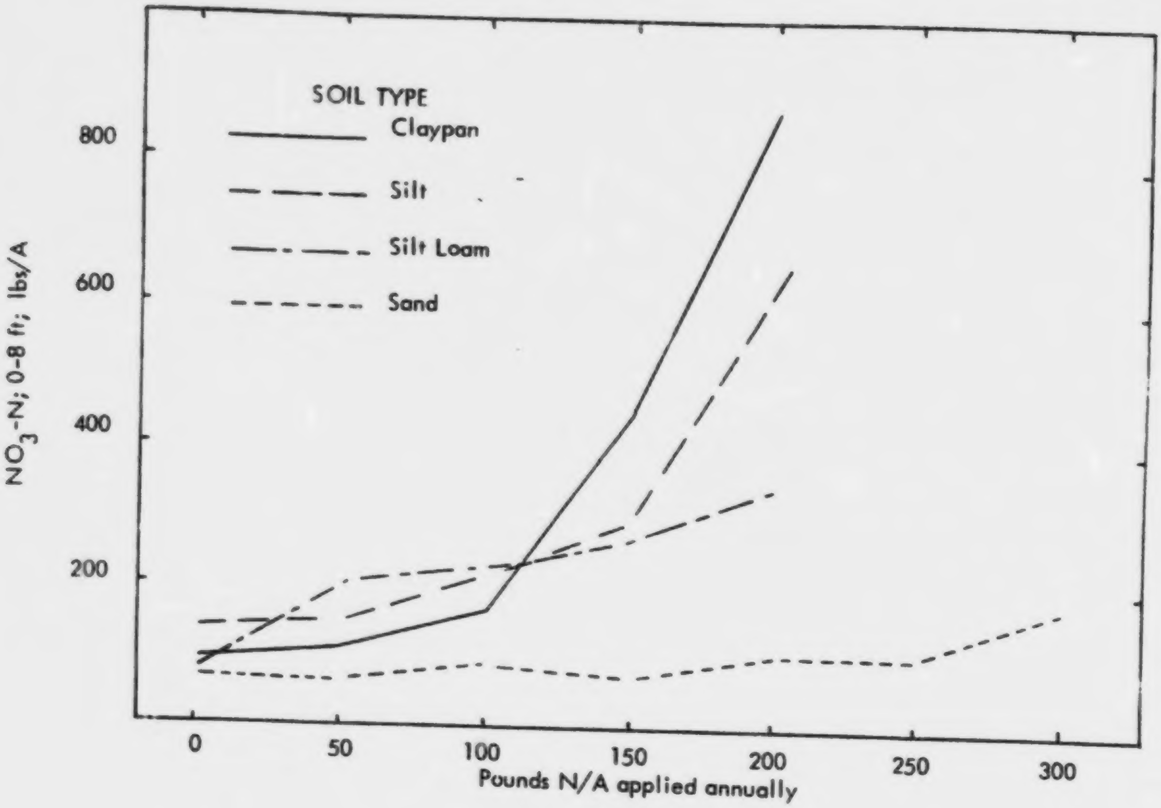

FIGURE 3

NITRATE NITROGEN IN SURFACE EIGHT FEET OF SOILS AFTER ANNUAL APPLICATIONS OF NITROGEN FERTILIZER FOR SEVEN YEARS TO CONTINUOUS CORN

supplied by now exhausted soils, or are furnishing the nutrient elements to other land that had been leached of minerals in the geologic past. Through proper management soils are producing an abundance of food for a growing population. Without these chemical soil amendments the United States would be a food importing nation. Despite liberal fertilizer use, crops are removing more nitrogen and minerals than are being added in soil amendments.

Many shallow wells in rural Missouri contain sufficient nitrate to affect the efficiency of livestock production. Most of the nitrate contamination has been the result of leaching from livestock feeding operations. Only in a few isolated cases could the association of nitrates in surface or groundwater, that could affect livestock, be associated with losses from fertilized farm fields.

Minimum concentrations of nitrate (and phosphate) that will stimulate eutrophication is of little concern when consumed by livestock. Both of these ions, as well as other soil minerals, have entered both streams and ground water during the period of landscape development. Most of these nutrients have been transported in sediment through losses from erosion. It has only been since waste problems of industrial and metropolitan areas have multiplied that attention has been given to chemical fertilizers as sources of nitrates and phosphates in streams. Other elements in water that could have had their origin from mineral weathering are now of little concern.

Relatively little data is available on the portion of plant nutrients in water originating from different segments of our economy. Most soil chemistry research concludes that with good management leaching losses of phosphates are too small to be of concern and the major portion of nitrogen applied in fertilizers is absorbed by crops. It has also been generally assumed that losses of nitrogen per unit area from soil organic matter in past years was probably greater than at the present time with liberal use of industrially produced nitrogen.

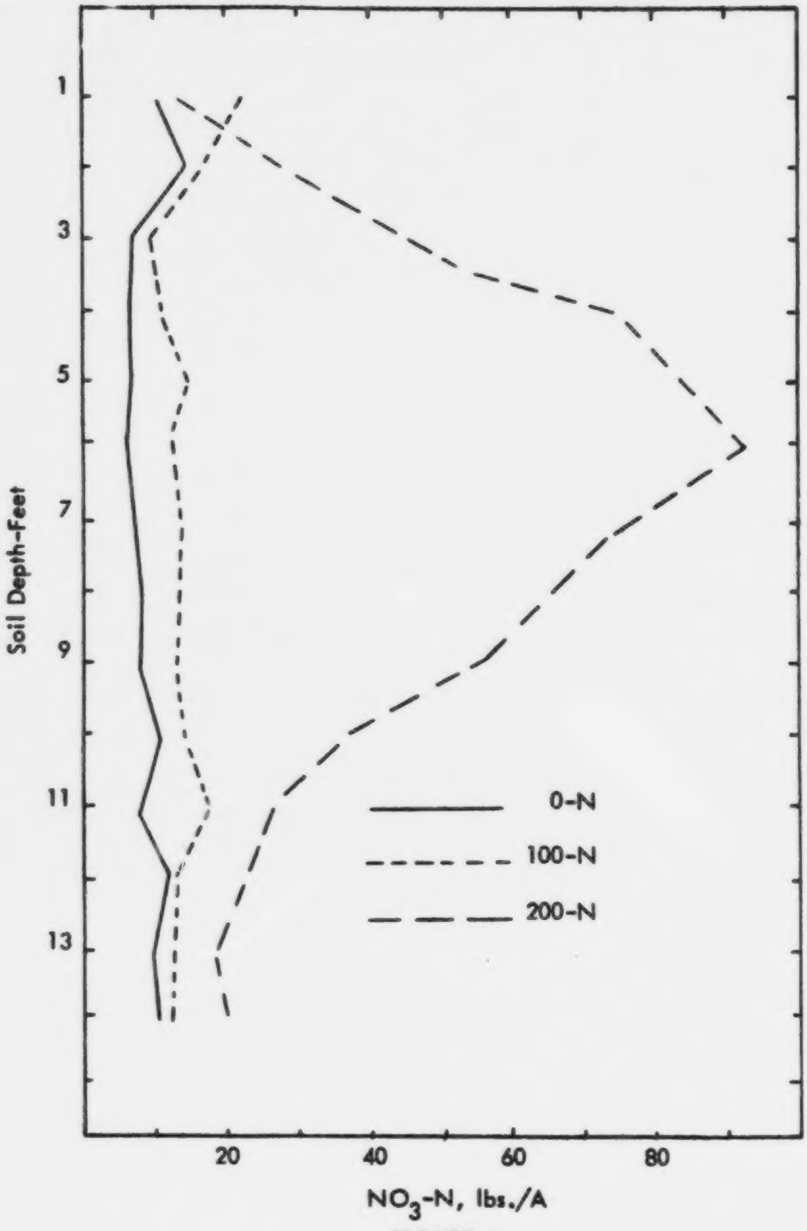

FIGURE 4

DISTRIBUTION OF NITRATE-NITROGEN IN THE PROFILE OF A SILT SOIL AFTER SEVEN YEARS OF ANNUAL APPLICATION OF NITROGEN FERTILIZER TO CONTINUOUS CORN

10.

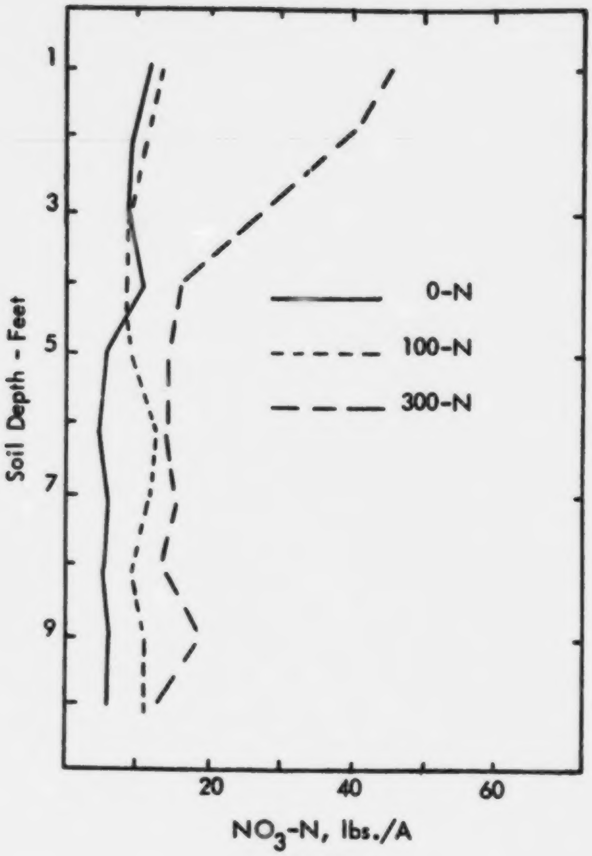

FIGURE 5

DISTRIBUTION OF NITRATE-NITROGEN IN THE PROFILE OF A SANDY LOAM SOIL AFTER SEVEN YEARS OF ANNUAL APPLICATION OF NITROGEN FERTILIZER TO CONTINUOUS CORN

There is little question that some of the nutrients applied in chemical fertilizers is moving into both surface and ground water. The amount will depend on many factors. The percentage is thought to be relatively small, but generalized statements cannot be made. One of the best means for purifying polluted water is for it to percolate through soil (10). Information is required on the nutrient content of percolates from soils receiving different treatments. Where the applied nutrients correct deficiencies, plant cover and transpiration is increased. It is possible that nutrient losses may be less where good fertilization practices are followed than on unfertilized soils. However, if future pollution controls for streams will require no reduction in present quality, the sources and amounts of nutrients entering streams must be known.

Chemical fertilizers are essential if our people are to be well fed. Crop management must be adjusted to obtain maximum efficiency of applied nutrients. The quantity of fertilizer nutrients added in crop production should not be in excess of plant needs.

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CATTLE FEEDLOT WATER QUALITY HYDROLOGY

T. E. Norton,[1] P.E. and R. W. Hansen,[2] P.E.

The mass production of beef in confinement feeding operations has become a sizable industry in recent years. Economics of size for specialized beef feedlots indicate the trend will continue towards large feeding operations. An example of one large feeding operation is at Greeley, Colorado where approximately 100,000 head of cattle are fed continuously.

The size of the feedlots and the manure production, which is about 64 pounds per day per animal (1), is indicative of the potential problems. The actual pollution may result from the disposal of the manure in two forms. One form is the solid waste which is mechanically removed from the surface of the feedlot and used as fertilizer on crop land. The other is the liquid runoff wastewater resulting from precipitation, which, if not impounded, finds its way to the natural water courses. This paper is concerned only with the runoff wastewater.

The quantity and the concentration of pollutants in the runoff are both of interest. The quantity of runoff is a function of the hydrologic conditions, which include rainfall intensity and duration, lot slope, and length of overland flow. The pollution quality of the runoff requires a determination of how much organic and inorganic matter is suspended in the wastewater and removed with it. The organic pollutant considered in this study was the ultimate combined BOD and the inorganic was the dissolved solids content and alkalinity. Additional determinations of conductivity, pH, and volitale solids were also made.

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The overall objective of the study was to determine if the hydrology characteristics could be correlated with the quality characteristics through a modification of the flat plate model of overland flow. The results of the correlation could then be used to predict the quantity and quality of the runoff from existing feedlots.

Equipment and Procedure

The field equipment used to collect the data for the correlation consisted of two basic units. One was the rainfall simulation equipment and the other was the sample collection and control device.

The rainfall simulation equipment used was similar to that used previously by Tovey (2). It included a trailer-mounted water recirculating unit and a sprinkler head operating inside a circular shield. The trailer-mounted water recirculating unit provided water storage and pumping capacity to allow from 0.25 to 1.25 in/hr of rain to be put on the test plot.

The runoff control and sample collection equipment included a 9½' X 3' test area, within the sprinkler pattern, enclosed by a 10-gauge reinforced sheet metal fence approximately 9 inches high. Eight rain gauges were located at uniform intervals along the sides to record application rates. The test area was drained into a catch basin equipped with sampling equipment, and a Stevens continuous float level recorder.

This equipment was transported to feedlots currently in use, and set up for each of the experimental runs. Eighteen separate runs were made at 13 different feedlots in north-central Colorado. When the equipment was set up, it enclosed a lot area, with an undisturbed manure surface, of approximately 28 square feet. The catch basin provided storage for all of the runoff from a run. The level recorder provided the time versus volume record of the runoff. Additionally, the equipment was placed so that the lot slope was parallel to the length of the test plot. The slopes on the individual runs varied from 1 to 12.5 percent. Once the equipment was set up and the slope and area of the test plots were determined, the rainfall event was started. Then, when runoff started, samples were taken for laboratory analysis on an hourly basis.

The data obtained from the field measurements were used to determine the runoff-rainfall relationship. The runoff samples were analyzed, and the resulting pollution concentrations were correlated with the runoff data.

Hydrology

Runoff from developed surfaces was investigated by Izzard (3), resulting in a dimensionless hydrograph of overland flow. Using this hydrograph as a basis and modifying it to fit the conditions of undeveloped cattle feedlot surfaces, results in the dimensionless hydrograph shown in Figure 2. The hydrograph of Figure 1 is based on a unit width of overland flow and to be practically useful, requires knowledge of:

1. The maximum runoff rate per unit width.
2. The time runoff starts.

3. The time runoff becomes constant.
4. The time rainfall ends.
5. The volume of water that will run off after the end of the rain.

The necessary relationships between these factors are shown in the following equations:

$$q_e = \frac{iL}{43{,}200} \qquad \text{(eq - 1)}$$

$$\beta = \frac{60 q_e t_a}{V_o} \qquad \text{(eq - 2)}$$

$$V_o = \frac{L^{4/3}}{32.4}\left[\frac{i\nu}{gs}\right]^{1/3} \qquad \text{(eq - 3)}$$

$$t_e = \frac{120 S_N}{i} + \frac{44.4}{i}\left[\frac{i\,L\nu}{gs}\right]^{1/3} - t_o \qquad \text{(eq - 4)}$$

$$t_o = 0.45\left[\frac{S_N}{i}\right](60) \qquad \text{(eq - 5)}$$

Where:
i = rainfall intensity, in/hr
L = length of the lot, ft
q_e = rate of overland flow at equilibrium per unit width, ft^3/sec-ft
β = dimensionless runoff ratio after the end of rain
R = dimensionless runoff ratio before constant runoff
V_o = volume of water in storage that will run off after the rain stops, ft^3/ft
ν = kinematic viscosity of the water, ft^2/sec
g = acceleration of gravity, ft/sec^2
s = slope of the lot, ft/ft
S_N = the amount of water stored in the manure that will not run off, in. of rain
t_a = any time after the end of the rain, min.
t_o = the time runoff starts
t_b = any time between the start of runoff and the time runoff becomes constant, min.
t_e = the time runoff becomes constant, min.

Equations 1 and 2 were developed by Izzard (3) and Equations 3, 4 and 5 were developed by Norton (4) for application to feedlot surfaces. They were based on laminar flow conditions and a Reynolds number less than or equal to 4000 (5), which results in a laminar

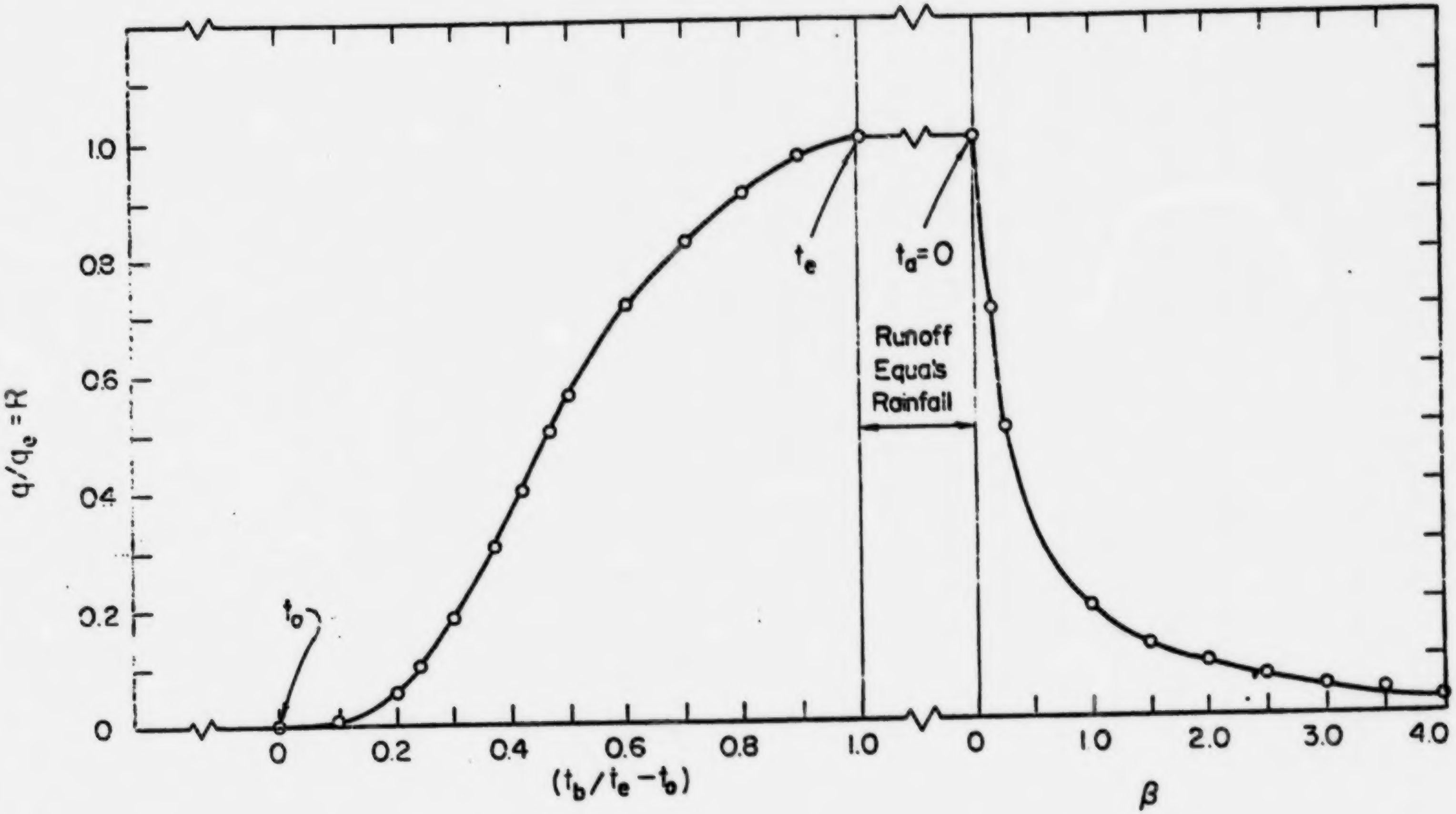

Figure 1. Modified Dimensionless Hydrograph of Overland Flow

flow limitation in terms of the rainfall intensity, length of lot and kinematic viscosity of:

$$\frac{iL}{\nu X\ 10} = 432 \qquad \text{(eq - 6)}$$

The hydrograph indicates that all of the rain runs off after time t_e and therefore that the water which does not runoff is stored in the manure soil complex. This is demonstrated in Figures 2 and 3. Figure 2 shows a plot of the surface storage measured, using Troxler nuclear moisture equipment, compared to the surface storage observed from the volume versus time graph of each run. Figure 3 shows a plot of the average rain rate obtained from rain gages compared to the runoff rate observed during each run. The resulting indication is that for rain durations used in this study, 2 to 8 hours, the infiltration to the ground water is so small that it can be neglected when determining the total runoff from cattle feedlots. Additional support for this conclusion comes from the fact that the manure was observed to be a dry hard crust, 2 to 4 inches below the surface of the manure after the runoff had ended.

The use of Equations 1 through 6 requires the determination of the rainfall intensity and the amount of surface storage. The rainfall intensity is a design term and its variation with storm frequency and duration, in equation form, can be given by (6):

$$i = \frac{CT_y{}^m}{(t_d + d)^n} \qquad \text{(eq - 7)}$$

where: c, d, m and n are constants determined from a given set of storm records (8)
T_y= storm frequency, yrs.
t_d= storm duration, min.

This rainfall intensity - duration - frequency information is also

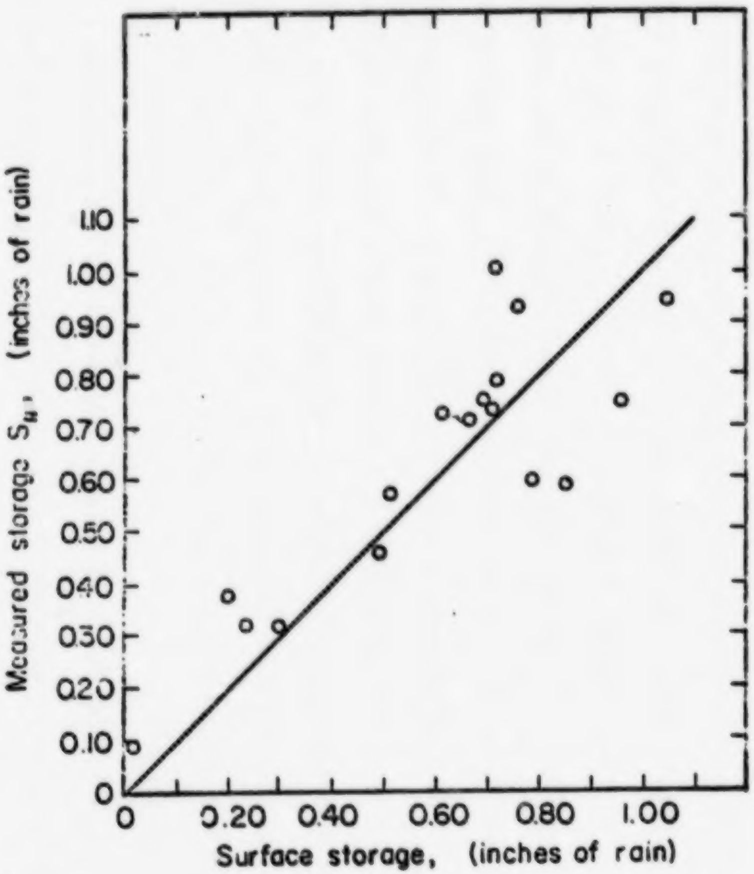

Figure 2. Measured Storage Versus Observed Storage from Hydrograph

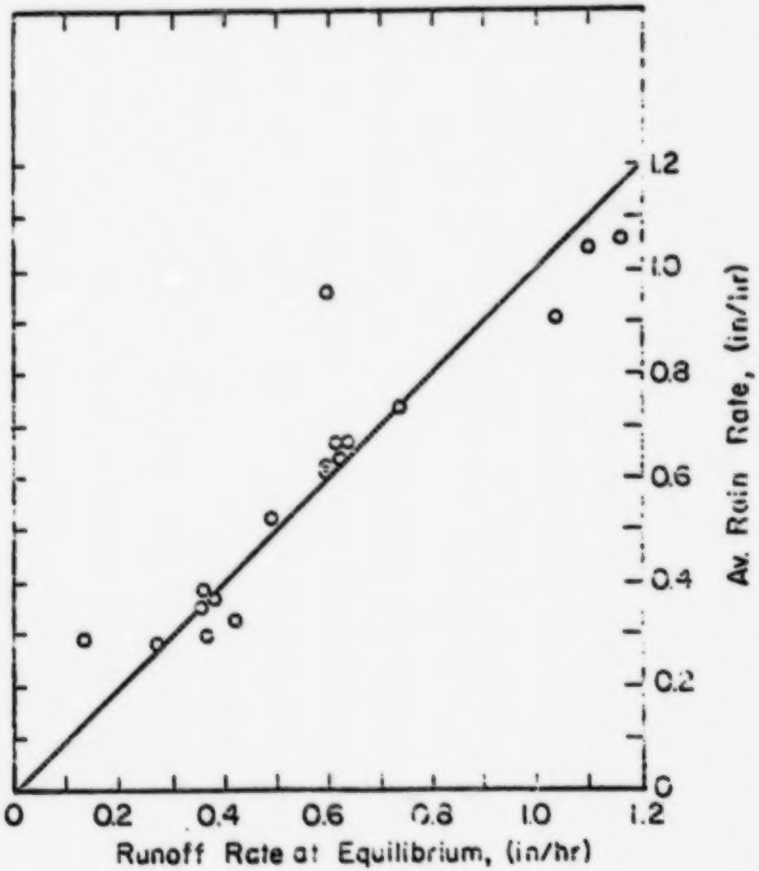

Figure 3. Rain Rate Versus Runoff Rate

available in graphical form for all first order Weather Bureau stations in the United States (8). Substitution of Equations 5 and 7 into Equation 4 and setting the time to constant runoff equal to the duration of the storm gives the following equation:

$$t_d = \frac{93\ S_N\ (t_d + d)^n}{C\ T_y^{\ m}} + 44.4 \left[\frac{L\nu}{gs}\right]^{1/3} \left[\frac{(t_d + d)^n}{C\ T_y^{\ m}}\right]^{2/3} \qquad \text{(eq - 8)}$$

Equation 8 gives the storm duration, t_d, that results in the maximum rate of runoff because runoff equilibrium is attained at t_e and additional rain will runoff at the supply rate.

The surface storage, S_N, is also a design factor and is primarily a function of the antecedent weather conditions. Miner (9) observed the surface storage of cattle feedlots to vary from 0.06 to 0.6 inches of rain. A similar range of surface storage was observed on the lots included in this study as shown on the arithmetically normal frequency distribution of Figure 4. The mean value of surface storage shown on Figure 4 is 0.64 which is higher than the upper limit suggested by Miner. This is believed to be due to the fact that all runs in this study were conducted in the summer during relatively dry lot conditions and consequently high storage capacities.

Using Equations 1 through 8 and Figure 1 allows calculations of the unit width hydrograph of overland flow assuming a reasonable surface storage from Figure 4. Flood routing of the flow obtained from the overland flow hydrograph will provide data for the design of the drainage collection system.

Pollution

The pollution characteristics previously mentioned were correlated with an effective depth of overland flow. This effective depth

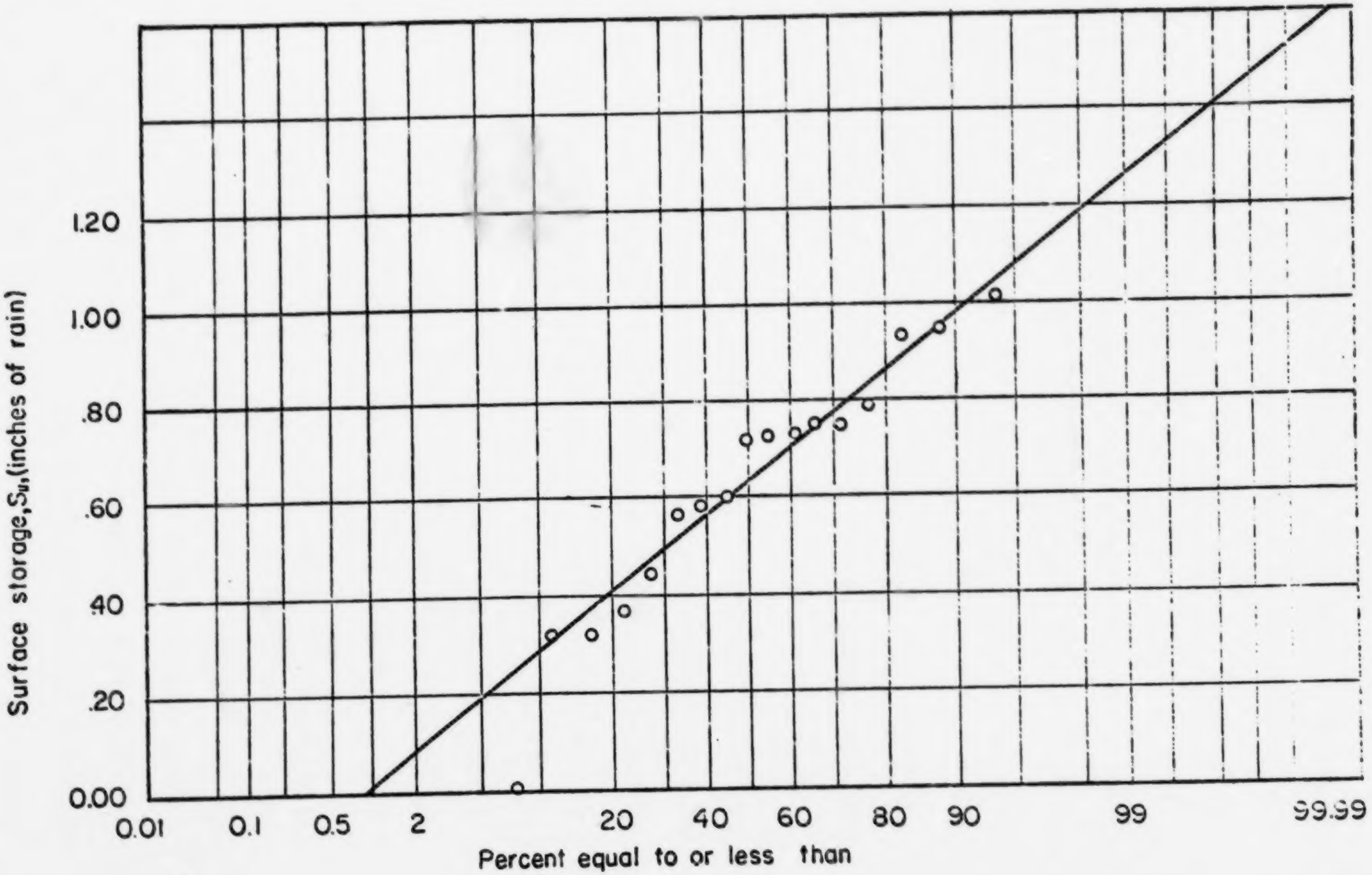

Figure 4. Frequency Plot of Surface Storage

is a modification of the depth of overland flow derived from the flat plate model and is due to the channelling observed during the runoff event. The channelling reduces the surface area per unit volume of runoff, because of the increased depth of flow in the channels. It is therefore considered that the change in concentration of pollutants is negligible after the runoff reaches a channel. The fact that channelling occurs was also observed by Miner (9). The channelling relationship determined from this study is shown in Figure 5. The effective length of overland flow, in Figure 5 is the distance the runoff traveled before entering a surface channel. The plotted points are observed values from the individual runs, whereas the arrows represent runs in which no channelling was observed. The lack of channelling at the lower slopes is because the length of the test area, approximately 9½ feet, was not sufficiently long to allow for channel formation. This points out a need for additional investigations using longer test areas or full-scale cattle feedlots to determine the validity of the effective length term when used beyond the range of observed values.

The effective depth of overland flow was determined to be (10):

$$\overline{D}_s = \frac{3}{4}\left[\frac{3\ q\ L_s\ \nu}{L\ gs}\right]^{1/3} \qquad \text{(eq - 9)}$$

All of the terms in the right side of Equation 9 are constants for a given feedlot surface except the rate of flow, q, which varies in accordance with the overland flow hydrograph. Therefore, the correlation of $\overline{D}_s$ with the concentration of pollutants will allow these concentrations to be determined at any time during the runoff. The graphical representation of $\overline{D}_s$ versus ultimate combined BOD, (BOD, L_j),

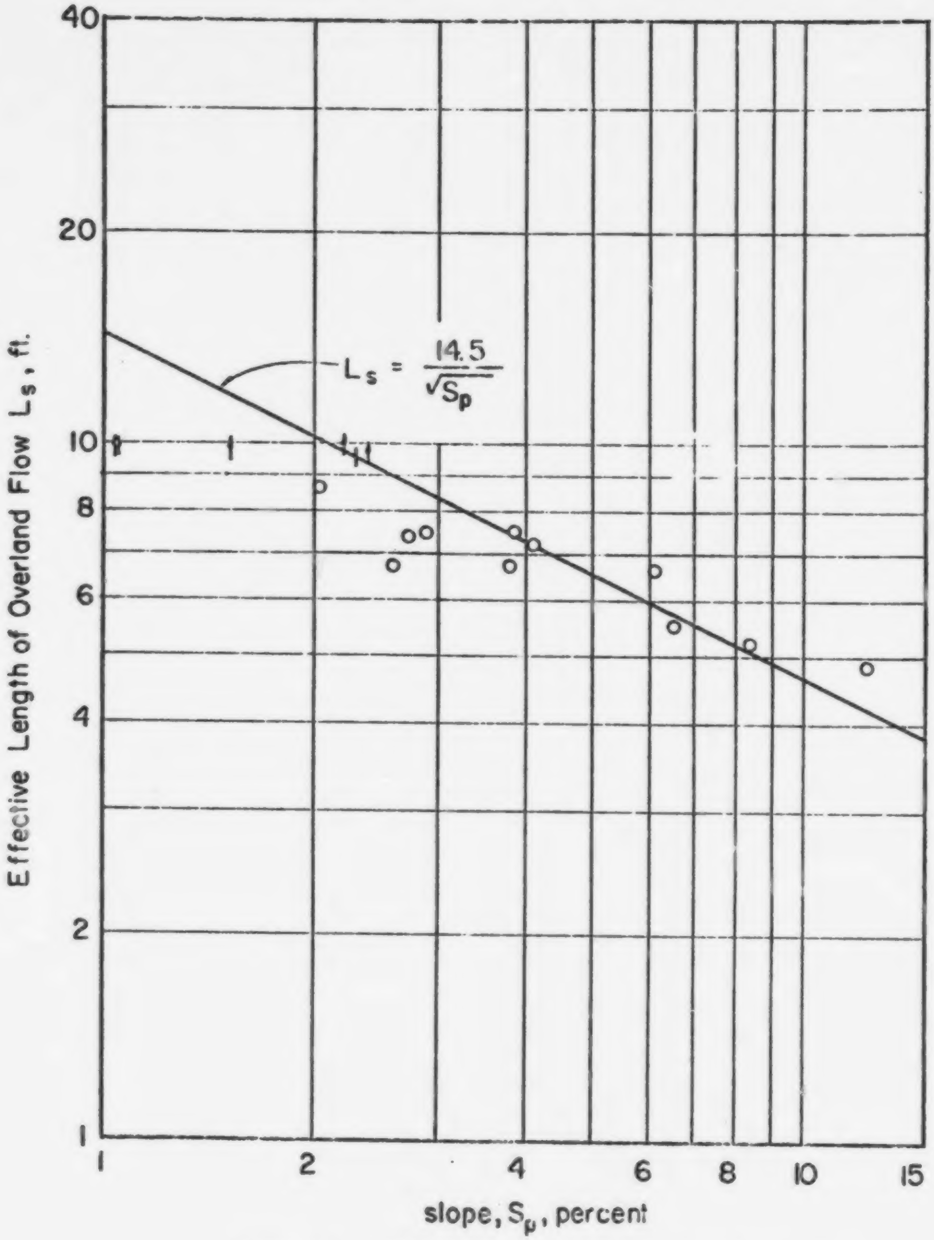

Figure 5. Effective Length of Overland Flow Versus Percent Slope

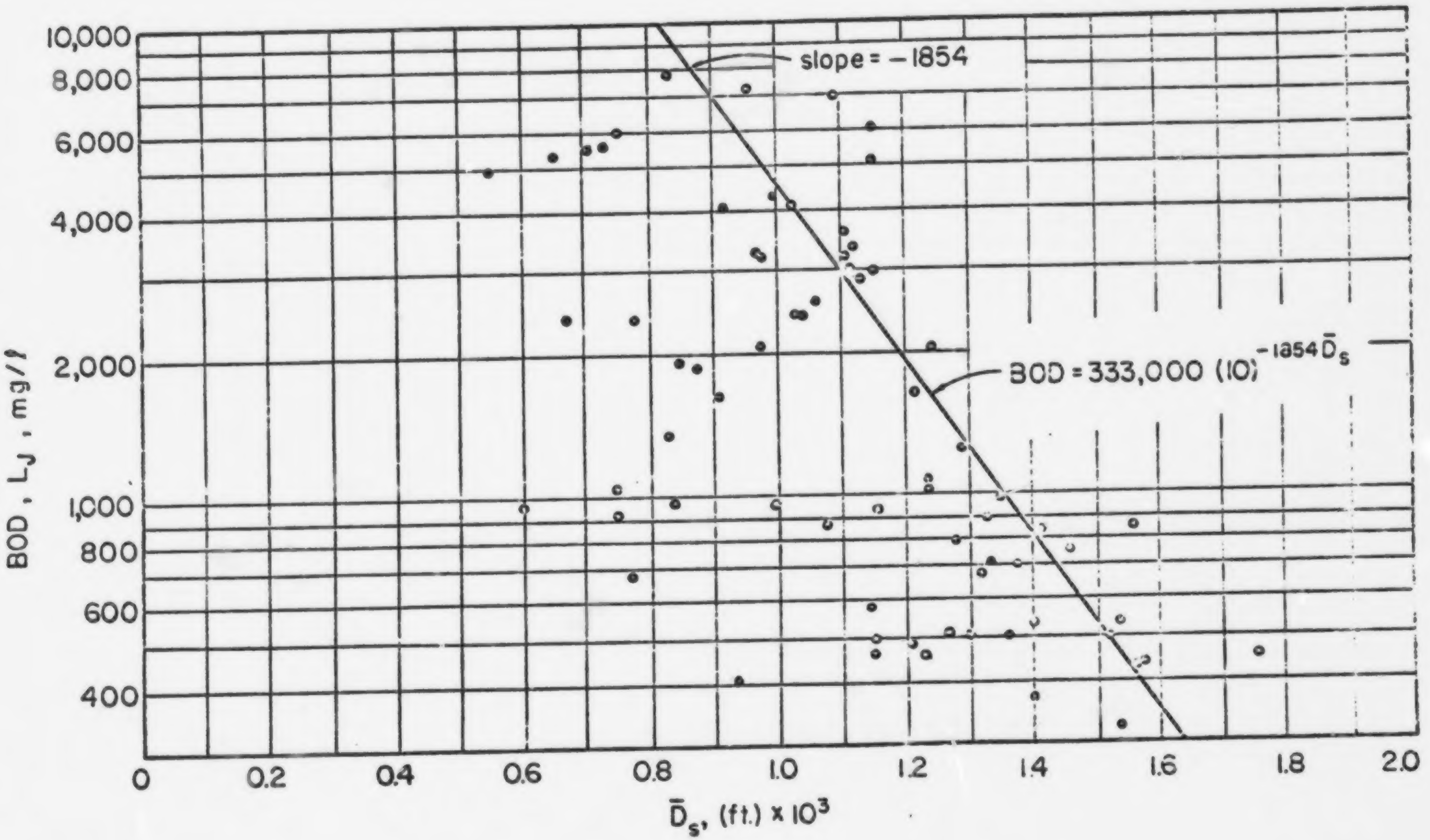

Figure 6. BOD, L_j Versus $\bar{D}_s$,

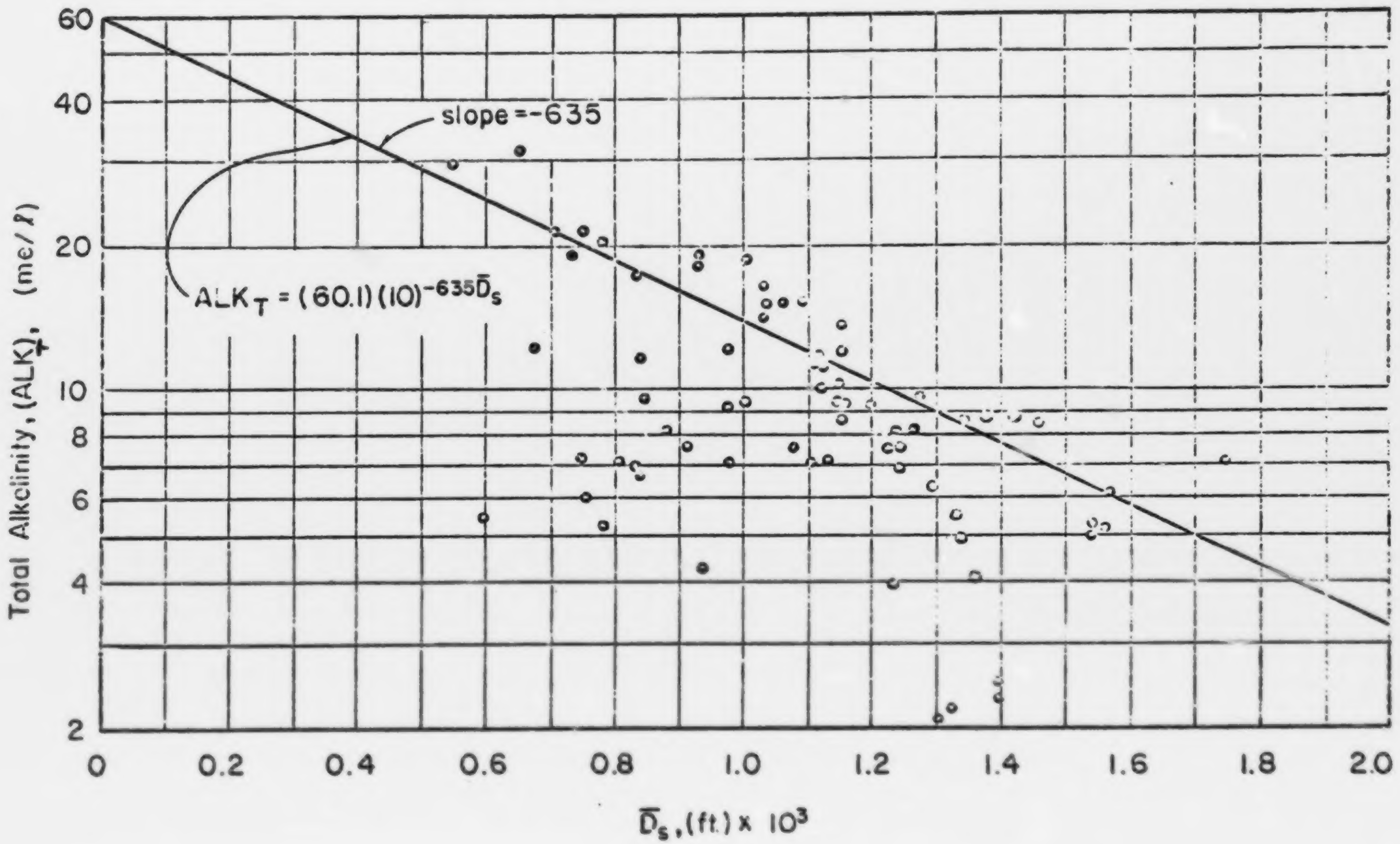

Figure 7. Alkalinity Versus $\bar{D}_s$

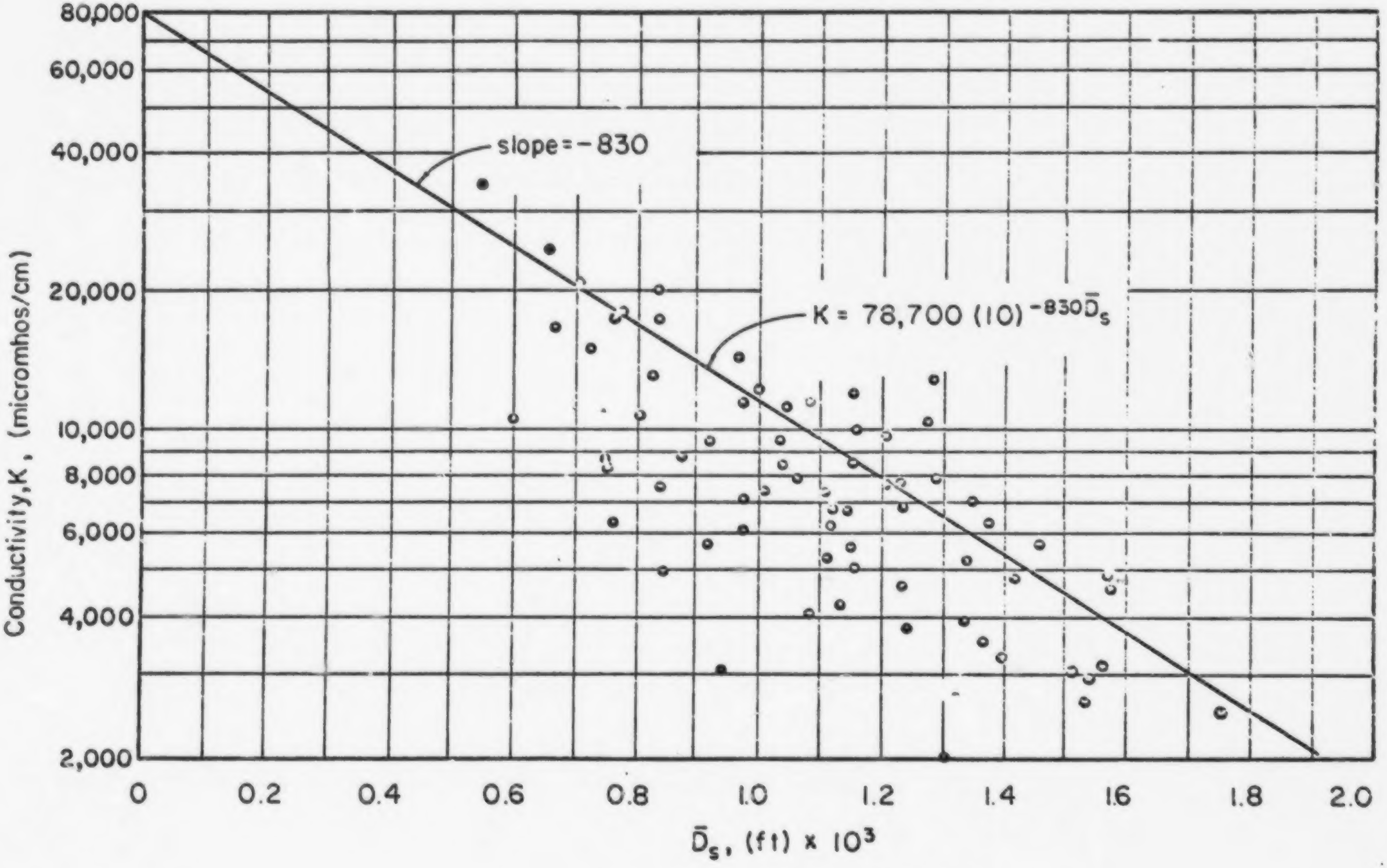

Figure 8. Conductivity Versus $\bar{D}_s$

total alkalinity, (Alk_T) and conductivity (K) are shown in Figures 6, 7 and 8 respectively.

The equations of the lines shown on Figures 6, 7 and 8 are the best fit of the upper limit of the concentrations expected at a given $\bar{D}_s$. The upper limit consideration is due to the change in the characteristics of the manure with time. This change with time has been investigated by Grub et. al. (11). They indicate that the BOD in the runoff can either increase or decrease with time, depending on the feed ration. This may at least partially explain the scatter in the data of Figures 6, 7, and 8.

The ultimate combined BOD values in Figure 6 were calculated from manometrically determined, 5 day-20°C BOD values and the equation:

$$BOD_5 = 0.716 \, (BOD, L_j) \qquad \text{(eq - 10)}$$

Equation 10 is the reduced form of an equation developed by Jex (12) for cattle feedlot wastewater and in this form is applicable only at 20°C for the 5 day BOD. Additionally, Jex (12) showed, by dilution methods, that the ultimate combined BOD at 20°C for undiluted beef cattle manure to be 45,940 mg/l. This is significant because it establishes 45,940 mg/l as the upper limit of BOD in Figure 6.

The maximum conductivity of beef cattle manure established by Jex (12) is 81,000 micromhos/cm which is very nearly the same as the intercept of Figure 8.

The alkalinity data obtained from the composite sample of each run were reduced to the three forms, plus CO_2, using the equation given by Fair et. al. (13). The range of values obtained for the three forms of alkalinity are shown in Table 1.

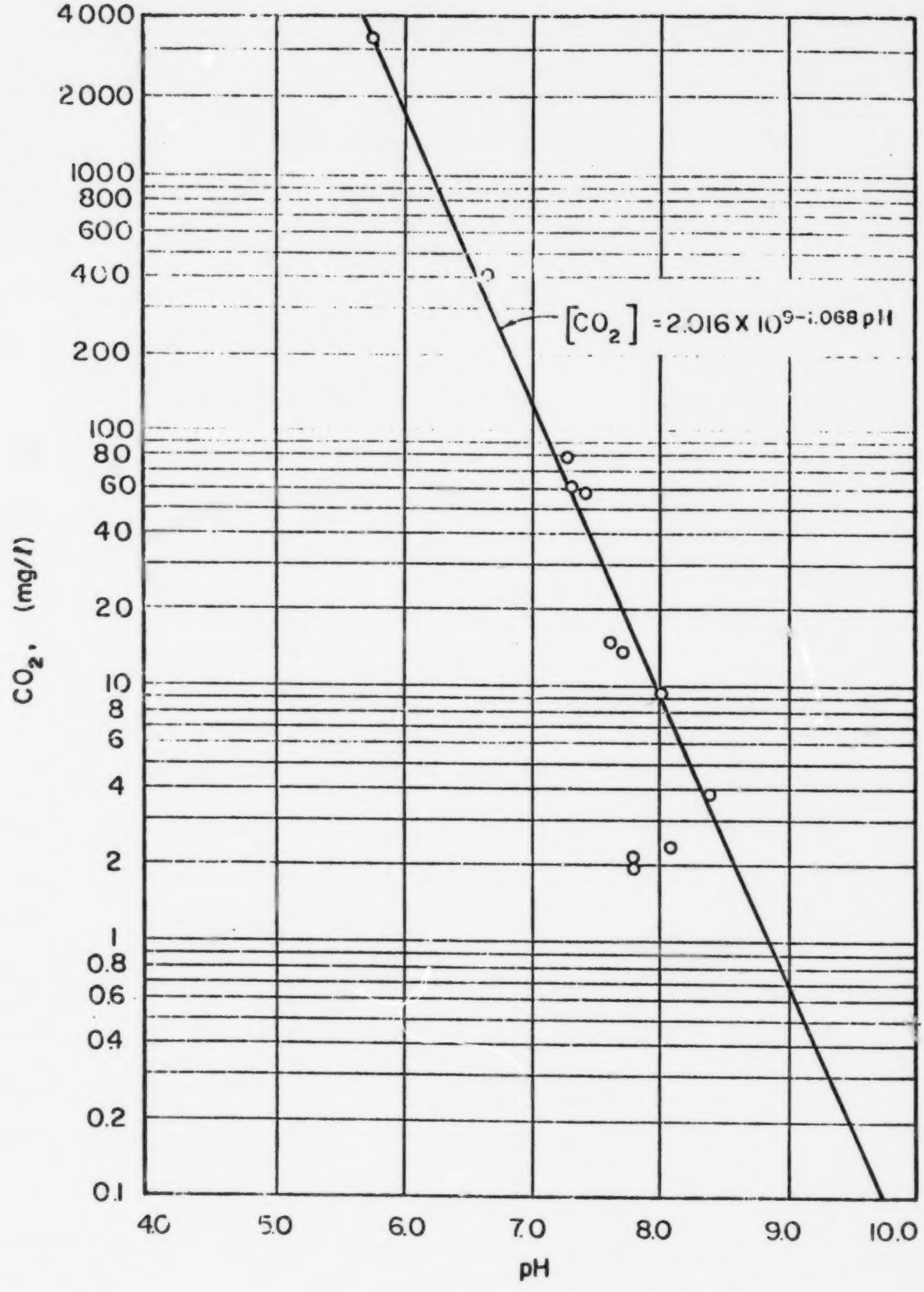

Figure 9. CO_2 Versus pH

Table 1. Forms of Alkalinity for Cattle Feedlot Runoff

Ion	Range of Concentration me/1
HCO_3^-	2.5 to 21.5
$CO_3^=$	0.005 to 0.673
OH^-	0.00001 to 0.03

The CO_2 values obtained were plotted versus pH of the wastewater as shown in Figure 9. The solids data obtained from laboratory analysis of the runoff samples are shown in Figures 10, 11 and 12.

Estimating the forms of alkalinity, the CO_2, pH or solids content of the runoff at any time can be accomplished by calculating the $\overline{D}_s$ as previously described and using the $\overline{D}_s$ graphs in conjunction with the equation or graph of the desired wastewater characteristics. The only exception is the determination of settleable suspended solids which were so variable within individual runs that a frequency distribution was used to represent this information.

What is generally of more interest than the concentration of pollutants at some particular time and flow rate, is the composite concentration of the wastewater in a holding pond or treatment unit. The composite BOD of a design storm can be estimated by graphical integration of the overland flow hydrograph. This is accomplished by taking finite units of time and multiplying them by the average rate of runoff for that time, resulting in an incremental volume of runoff. Also, using the average rate of runoff, $\overline{D}_s$ for the incremental time can be calculated from Equation 9 and the BOD for the incremental volume can be obtained from Figure 6. Then the BOD can be volumetrically composited by multiplying the incremental volumes by

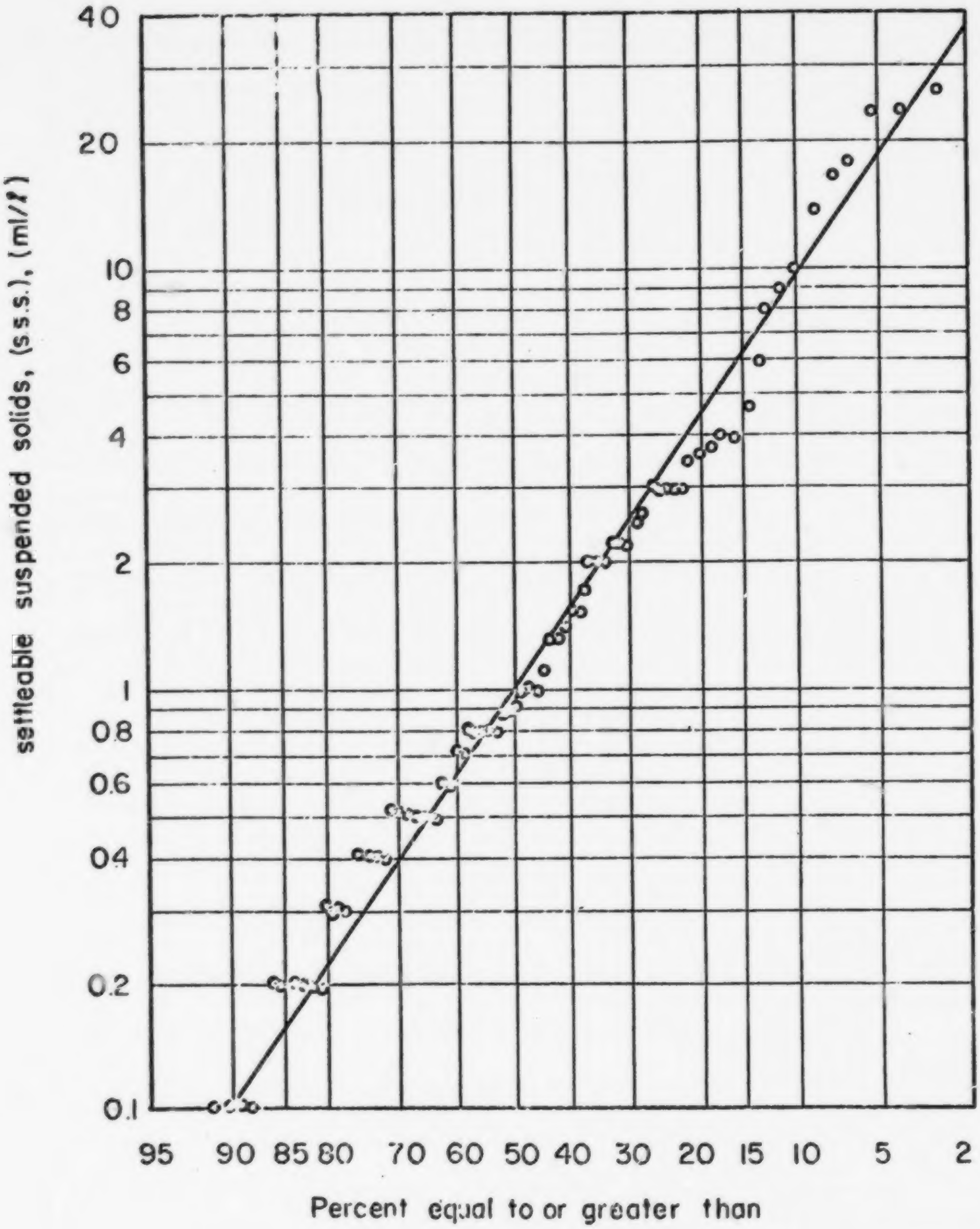

Figure 10. Frequency Distribution of Settleable Suspended Solids

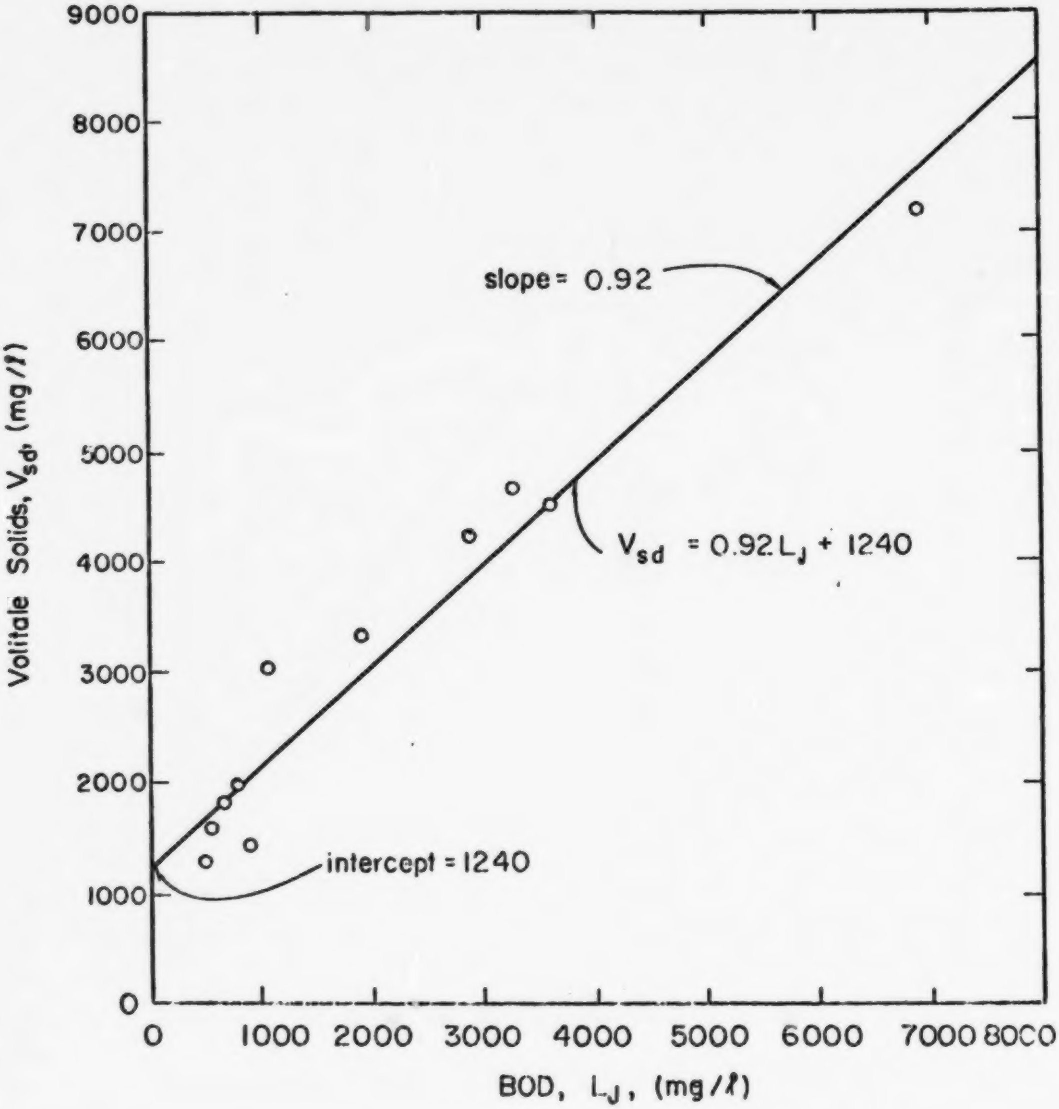

Figure 11. Volital Solids Versus BOD, L_j

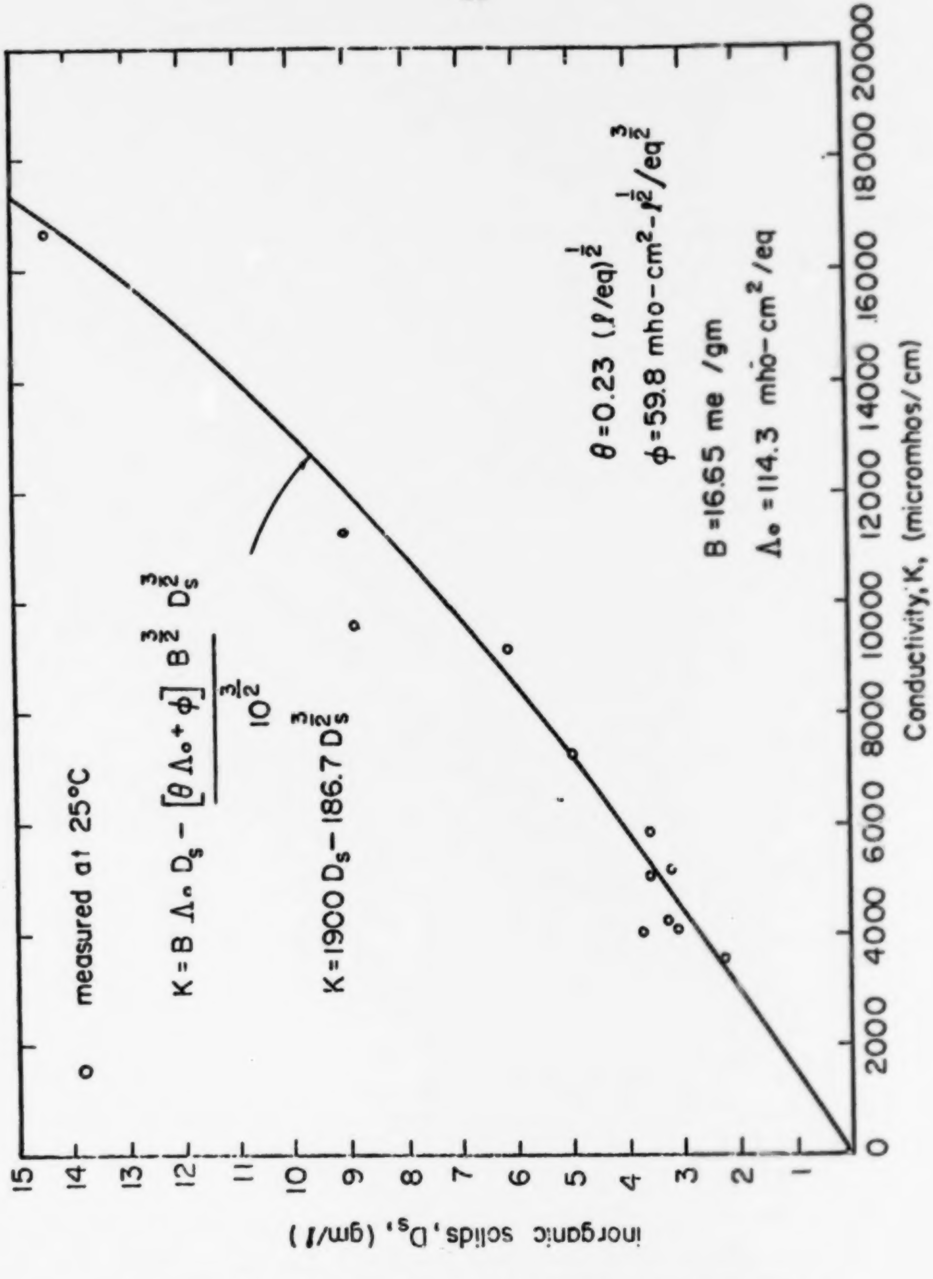

Figure 12. Inorganic Solids Versus Conductivity

their respective BOD, summing the products and dividing by the total volume. The above procedure was varified in this study by mathimatically compositing the individual BOD runoff samples and comparing the results with the composite BOD sample taken from the catch basin after runoff had stopped. This comparison is shown in Figure 13.

The alkalinity and conductivity can be similarly composited with the exception that conductivity should be converted to inorganic solids, then the inorganic solids volumetrically composited and converted back to conductivity. This exception is do to the nonlinear relationship between conductivity and inorganic solids.

Example BOD Prediction

The length of the feedlot pen of interest is 250 feet and the slope is 2%. Assuming a design storm rainfall intensity of 1.7 in/hr and a mean value of surface storage from Figure 4 of 0.64 in., the time t_o from Equation 5 is:

$$t_o = 0.45\left[\frac{S_N}{i}\right] 60 = 0.45 \left[\frac{0.64}{1.70}\right] 60 = 10 \text{ min}$$

Assuming a wastewater temperature of 74°F resulting in a kinematic viscosity of 1×10^{-5} ft^2/sec, the time to constant runoff from Equation 4 is:

$$t_o = \frac{120 S_N}{i} + \frac{44.4}{i} \left[\frac{i\ L\ \nu}{gs}\right]^{1/3} - t_o$$

$$= \frac{120\ (0.64)}{1.70} + \frac{44.4}{1.70} \left[\frac{(1.70)(250)(1 \times 10^{-5})}{(32.2)(0.02)}\right]^{1/3} - 10 = 41 \text{ min}$$

from Equation 3, the volume of water that will run off after the rains stop, V_o, is:

$$V_o = \frac{L^{4/3}}{32.4} \left[\frac{i\nu}{gs}\right]^{1/3} = \frac{(250)^{4/3}}{32.4} \left[\frac{(1.70)(1 \times 10^{-5})}{(32.2)(0.02)}\right]^{1/3} = 1.46\ \frac{\text{ft}^3}{\text{ft}}$$

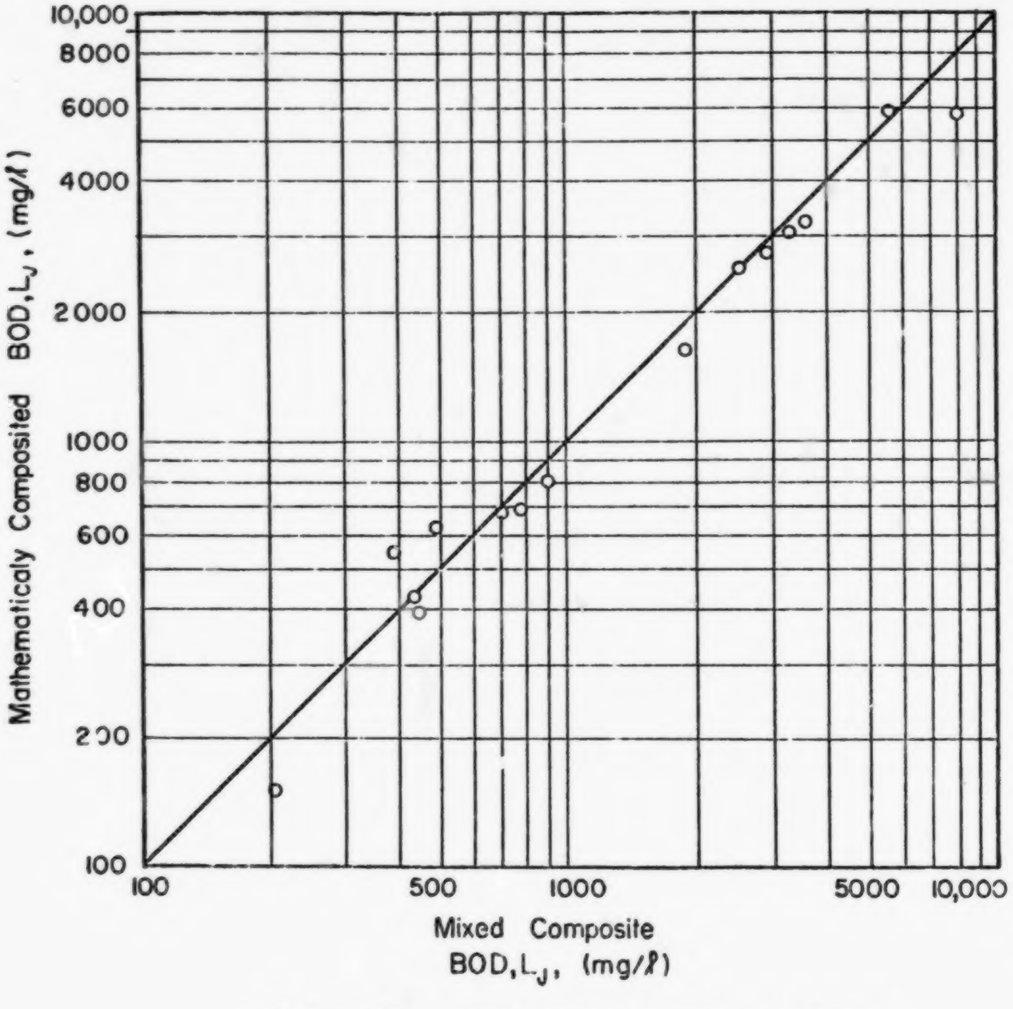

Figure 13. Mixed Composite BOD, L_j Versus Mathematically Composited BOD, L_j

The rate of overland flow at equilibrium, q_e, from Equation 1 is:

$$q_e = \frac{i\ L}{43{,}200} = \frac{1.7\ (250)}{43{,}200} = 9.85 \times 10^{-3}\ \mathrm{ft}^3/\mathrm{sec\text{-}ft}$$

and the runoff ratio after the end of the rain, ,from Equation 2 is:

$$\beta = \frac{60 q_e t_a}{V_o} = \frac{(60)(9.85 \times 10^{-3})}{1.46} t_a = 0.4 t_a$$

Then assuming that the duration of the storm is equal to the time to constant runoff, and assuming various times from the start of runoff and the end of the rainfall, the unit width hydrograph shown in Figure 14 can be developed using the R and β ratios from Figure 1. Using the plotted points of Figure 14 as the midpoint of the incremental volume and the average runoff rate per unit width of the incremental volume, the various $\overline{D}_s$ values can be calculated from Equation 9, when L_s from Figure 5, is 10.2 ft. After obtaining the $\overline{D}_s$ values, the BOD, L_j for each $\overline{D}_s$ is obtained from Figure 6. The remaining calculation is simply the volumetric composition of the BOD, L_j. The necessary calculations are shown in Table 2, resulting in a composite BOD, L_j of 8396/10.43 = 800 mg/l and a volume of runoff per unit width of 10.45 ft^3.

Table 2

(1) Time Interval ΔT min	(2) Rate of Runoff $q \times 10^3$ ft^3/sec-ft	(3) Volume of Runoff ft^3	(4) Effective Depth of Overland Flow $\overline{D}_s \times 10^3$ ft	(5) BOD, L_j mg/l	(6) BOD, L_j X Volume ft^3 - mg/l
(Source of Information)					
Fig. 14	Fig. 14	(1)X(2)X60	eq - 9	Fig. 6	(3)X(5)
5	0.25	0.07	0.59	27,000	1890
5	2.07	0.62	1.19	2,060	1280
5	5.15	1.55	1.61	350	544
5	7.58	2.28	1.82	140	319
5	9.06	2.72	1.91	97	264
4	9.85	2.36	2.00	65	153
2	3.74	0.45	1.45	680	306
4	1.08	0.26	0.96	5,550	1440
5	0.39	0.12	0.68	18,300	2200
		10.43			8396

A similar calculation for a rainfall intensity of 0.17 in/hr requires 100 min. before runoff starts and 400 min. to constant runoff, the resulting $\overline{D}_s$ values are small, resulting in a composited BOD, L_j approximately equal to 10,000 mg/l. This BOD is higher than any observed in this study and some of the BOD values in the example are lower than any observed in this study, thereby demonstrating the fact that the prediction method proposed requires extrapolation of the data beyond the observed values. Therefore, additional information obtained from studies of runoff from full-scale feedlots would be advisable in determining the validity of this extrapolation in addition to the validity of the effective length term previously mentioned.

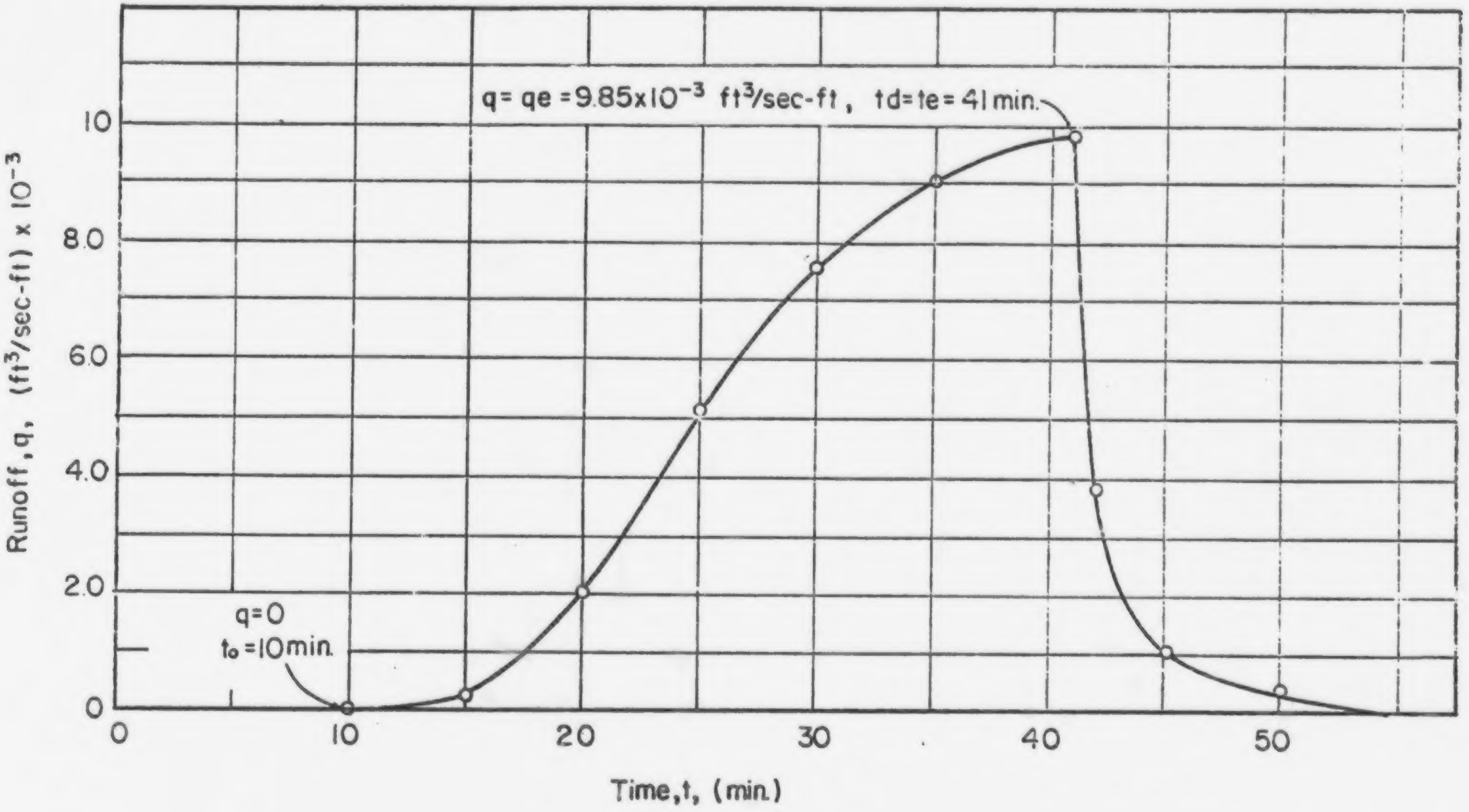

Figure 14. Example Unit Width Hydrograph of Overland Flow

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MAJOR PROBLEMS OF WATER POLLUTION CREATED BY AGRICULTURAL PRACTICES*

by

Walter F. Robohn**

It is a pleasure to be on your program this evening, representing the Federal Water Pollution Control Administration, to discuss some of the major problems of water pollution resulting from agricultural practices. This is a very broad subject so I will try to confine my remarks to those major problems pertinent to the area of the United States in which our office has prime responsibility for the administration of the Federal Water Pollution Control program. This area, the entire drainage of the Missouri, Souris, Red, and Rainy river basins includes parts of Montana, Wyoming, Colorado, Kansas, Missouri, Iowa, Minnesota, nearly all of South Dakota, and all of North Dakota and Nebraska. This area is about 1/6 of the total area of the 48 contiguous states. It has about 400,000,000 acres and a total population of about 8 million people. About 3.5 million of these people are classified as rural dwellers, but only about 1.5 million are actually classified as farmers and ranchers.

The magnitude of the water pollution abatement problem in this region can be vividly illustrated by considering the Nebraska-Iowa-Missouri reach of the Missouri River. Stream surveys indicate that this stretch of the river carries an organic pollution burden equal to that of the discharge of the untreated wastes of 80,000,000 people. This loading, exceeds by 10 times the human population of the basin. The population equivalent of the pollution caused by industrial activity may equal that of the population. The balance of the pollutional loading represents that caused by so-called natural sources and agricultural endeavors.

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*To be presented at the 13th Annual Great Plains Waste Water Design Conference to be held March 25, 1969 at Omaha, Nebraska.

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Agricultural and associated agri-business activities are common to the entire basin except some of the high mountain headwaters areas. Return flows from irrigated agriculture with loads of silts, salts, and nutrients affect nearly all the Western tributaries of the Missouri River. The Garrison Diversion which will bring one million acres under irrigation in the James, Souris and Red River Basins of North Dakota, will contribute heavy silt and salt loads to these Rivers.

The changing character of animal production, both feeding and processing is having a profound impact on the Missouri Basin. Only a decade ago, the major meat packing centers in the basin were concentrated in the Sioux City, Omaha, St. Joseph, and Kansas City areas. Today many of the packing plants are being moved closer to their source of the raw material - the tremendous feeder lots which have literally sprung up overnight. This decentralization of the packers to more rural settings where only limited water resources may be available makes for serious water quality control problems. The usual pollution problems of the meat packers are compounded by the vast feedlots in the same area.

Sugar beet processing which was formerly concentrated in the South Platte, North Platte, Yellowstone and Red River subbasins, has now appeared in the Kansas Basin. There is every reason to believe that the demand for beet sugar will keep rising and while no dramatic dispersion of this industry is forecast, any increase in sugar beet production and processing must be carefully watched because of the pollution potential.

In the Red River Valley the processing of potatoes, a seasonal operation as is sugar beet processing, is expanding at a great pace. The products are "easy-to-cook and serve table foods" and commercial starch. The waste control problems of this activity are complicated due to extremely rigorous climate of the Red River Valley. Many of the processing plants are close to the irrigated production fields. The vegetable processors of this area all have waste handling problems due to seasonal operation and rigorous climate.

The Missouri Basin Region is not a large milk producing area. Much of the milk consumed in the area is imported from adjacent basins. The Minnesota portion of the Red River Basin does, however, have many milk processing plants.

Sediment derived from land erosion constitutes by far the greatest mass of all the waste materials arising from agricultural operations. The Report of the Senate Select Committee on National Water Resources states that the suspended solids loadings reaching the streams from agricultural lands are at least 700 times the loadings caused by sewage discharges.

The Mississippi River system of which the Missouri River is a major tributary, dumps more than 500 million tons of sediment into the Gulf of Mexico annually. This amounts to almost one ton for every acre of farm land in the Mississippi Basin. The average sediment yields of the Missouri Basin exceed those of other basins due to the high percentage of areas especially susceptible to soil erosion. In the Missouri Basin, soil loss can easily exceed 100 tons per acre per year unless proper soil management programs are followed. It is this sediment load and not the municipal or industrial wastes that cause the Missouri River to be known as the "Big Muddy".

The 500 million tons of sediment carried by the river system includes about 17 million tons of plant nutrients. Of particular interest because of their affects on water quality are the 500,000 tons of nitrogen and 750,000 tons of phosphate contained in this sediment.

So far I have simply mentioned major activities which are contributing to water pollution. Let us now discuss some fundamentals of pollution of interest to this region. Generally speaking, pollution from any source can be placed into one of three categories: physical, chemical (sometimes called inorganic) and biological, which includes bacterial and viral pollution. In pollution from agricultural sources, the physical parameters such as temperature change, color, taste, odor and turbidity are closely connected with the chemical and biological phases. For example, an increase in turbidity, generally attributed to soil erosion, and the resultant sediment load, almost always is accompanied with an increase in chemical load and bacterial population. Inorganic chemical pollution usually is only one part of an overall pollution problem.

As an example, lets take a look at the Missouri River. Heavy rains cause large amounts of silt, debris and other solid materials to be carried into the river, as the river level rises, turbidity increases tremendously as does the biochemical oxygen demand (BOD) and bacterial count. After the river crests and falls back to lower stages, the turbidity, BOD and bacterial count all decline. This physical and biological pollution phenomena is the result of surface runoff of agricultural areas.

Lets talk about a specific cause of pollution, one resulting from meat production. Over 150 pounds of meat per capita are consumed each year. With the population booming and incomes rising, the demand for meat, and other farm produce, is bound to continue to rise. Animal husbandry specialists are working to find ways to produce a pound of meat at less cost. This search for economical production has lead to the large feeding operations in which as many as 100,000 head are fed in extremely close quarters, or to put it another way, the animal population per acre, in feedpens, has risen sharply. The cattle are fed their feed ground, mixed and otherwise prepared in these large lots. Feedlots are literally well mechanized "meat factories".

Last year, Iowa with over 2 million cattle on feed led the nation in numbers of slaughter beef animals fed. Nebraska was third, just below Illinois. There are over 46,000 feedlots in Iowa and over 24,000 in Nebraska.

A lot containing 10,000 cattle has a pollution potential equal to a city of from 80,000 to 180,000 people depending upon the waste parameter select for comparison. A major point of difference between normal municipal pollution loads and cattle feedlot loads is the mode of occurrence. A city contributes its load daily at a somewhat uniform rate. The feedlot pollution may accumulate on the ground and appear as a "slug" load washed into the stream after moderate to heavy rains. This partially decomposed material consists of animal feces, urine, fresh and some partially digested feed which is usually loaded with antibiotics and other chemotherapeutic drugs. Hay, straw and other fibrous materials also are a part of the slug reaching the stream. As this mass of material starts to move downstream, the bacterial count rises dramatically, not only the coliform organisms but also the streptococci and the salmonella groups. These groups contain pathogens which can cause contagious diseases and serious illnesses in both man and animals. The first parameter usually noted, however, is ammonia derived from the readily soluble urine. Ammonia almost immediately exhausts the oxygen and creates obnoxious septic stream conditions. Fish and other aquatic life soon die. As the ammonia is eventually coverted to nitrates, more problems arise. Water containing excessive nitrates can cause illness and death to both man and animals. Our Regional Office recently compiled a "Compendium of Animal Waste Control", which contains some major studies of the problem, some papers of more general interest and copies of legislation enacted to help control this problem.

*Most of the States in the Missouri Basin Region have either enacted feedlot legislation or regulations or are in the process of doing so. Enactment of legislation or the establishment of rules and regulations can and do assist, but by themselves will not cure a problem. Some regulations call for registration of feedlots handling over 300 to 500 feeder cattle or other animals or fowl with numbers adjusted to fit the potential waste loadings. For example, the Nebraska regulations call for registration of (1) any pen or other place of confinement with more than 300 feeder cattle, 100 beef cows, 100 dairy cows, 500 hogs, 2,000 sheep, 3,000 turkeys or 10,000 chickens, ducks or geese; (2) any lot, of smaller capacity, that is

*Insert on page 6A

The office also held a conference on animal wastes problems. Two hundred experts from 24 states participated in sessions. Work groups on inventory problems, regulations and research need was organized. They will serve as a focus for defining the information gaps and suggesting reasonable approaches.

located within 500 feed of a watercourse; or (3) any other feedlot that has a pollution potential. Any other operator not required to register his lot may do so if he wishes.

Such registration gives a State water pollution agency the location and magnitude of potential water pollution problems. The necessary remedial work to control pollution can be ordered under an appropriate State statute. Generally, the remedial work must at least prevent the carrying of wastes to watercourses by surface runoff coursing through the lot.

The most probable treatment methods consist of lagoons to handle the liquid portion of the wastes. The so-called dry or solid portions of the wastes will be stockpiled in a manner so that the drainage from the piles will not contribute to water pollution.

There have been stockpiles several city blocks long, a city block in width and over 20 feet in height awaiting some means of disposal. As you must realize, any rainfall on this pile will generate a considerable amount of liquid waste. The largely fibrous material does not decompose readily and does not lend itself to any conventional waste treatment process. The sheer volume of these wastes has thwarted most attempts to utilize them as soil conditioners or fertilizers. To date, just how to dispose of this large amount of solid waste has not been completely solved.

As pointed out earlier, the animals formerly were slaughtered and processed in a few large centers located directly on the Missouri River. Unwanted wastes were discarded directly to the river. This extremely undesirable means of waste disposal eventually lead to a public demand for better waste control and treatment, although it did not cause the extreme water quality degradation that is now occurring in smaller streams below feedlots and relocated meat processing plants. To properly control the wastes from meat processing plants, will require waste treatment facilities which will provide a degree of treatment generally thought unattainable a few years ago. In time past an industrial waste treatment plant capable of removing 65 to 75 percent of the BOD was considered an adequate installation. Today plants routinely removing 90 to 98 percent of the raw BOD may be inadequate as far as stream protection is considered. Even treated wastes are not stable. The small streams in the vicinity of the relocated meat processing plants simply cannot assimilate these treated effluent waste loading and remain in a condition acceptable to the citizens today.

The public acting through their congressmen and senators has demanded better water quality in the nations streams and lakes. A small stream receiving even these effectively treated wastes may become an unsightly mass of green algae and weeds. Fish and other aquatic life is discouraged, stifled, or even killed and what once was a pleasant creek or brook has become an ugly eyesore. Satisfactory treatment of these wastes will involve the usual secondary or biological treatment followed by a tertiary biological treatment which in turn will be followed by a nutrient removal process. Disinfection may be required in those localities where close downstream uses occur. Consulting engineers will be faced with many hours of brain work and pencil sharpening in the coming months to design such facilities. It is also true that many individual industries are going to have to re-examine their financial ledgers to discover ways to finance the required treatment. The past arguments against making these expenditures, such as threatening to move to another State or go out of business because their competition does not have to conform to strict treatment requirements no longer holds because all industrial plants in all States are now faced with the same requirements. The competition will be between consulting engineers to come up with an effective economical plan to provide the necessary treatment. Just what this cost will mean to the housewife when she purchases a steak has not been thoroughly researched, however, in other industries facing a similar problem, the extra cost has been about 1 percent to 2 percent and even now better designs are bringing costs down.

The sugar beet industry generally has not dispersed to the extent of the meat industry. Except for one or two new plants in the Missouri and Red Basins, it does not appear that it will do so in the near future.

Many studies have been performed on the treatment of sugar beets wastes using biological systems including activiated sludge, trickling filters, lagoons and other means. In general, pilot plant studies have not, to date, yielded consistant results. These wastes are deficient in nitrogen and phosphorous, and these nutrients must actually be added before conventional treatment schemes are effective. This raises costs and adds to operation and maintenance problems. One successful scheme involves a closed system with reuse of step process effluents. This not only prevents wastes from entering the stream but lowers the net water demand. At the end of the campaign the smaller volume of concentrated waste can be satisfactorily handled. Since most sugar beet mills are in areas faced with water shortages, this reuse of effluents becomes an additional benefit. Several plants in the South Platte Valley are converting to this recirculation scheme.

In the Red River Valley, the potato processing industry is attempting to adapt lagoons to the treatment of their wastes. In the past many of the waste treatment schemes included some storage of wastes with subsequent release of the waste during the high spring runoff. This never was completely satisfactory even when the volume of the wastes was small. The combination of low temperature, large volumes, nutrient deficiencies, and seasonal operation has given this industry some of the same problems of the beet sugar industry. Lagoons with supplemental aeration and nutrients derived from domestic sewage appear to have merits. A full scale test is under way at Grand Forks, North Dakota to develop design criteria.

Lagoons appear to provide acceptable treatment for vegetable processing wastes although care must be taken to consider the peculiar characteristics of the waste at each installation. Characteristics of the waste vary considerably with the vegetable being processed and the process used. Sugar content, pH, and salt are examples of variables encountered. Vegetable processing is a seasonal operation. When the processing is done during warm weather wastes handling by spray irrigation may also give good results if enough suitable land is available.

The wastes from animal feedlots, sugar beet and potato processing plants and vegetable canneries all have extremely high bacterial populations and biochemical oxygen demands (BOD). These wastes must be given some form of treatment which drastically reduces this population and reduces the BOD if water quality standards are to be met. Chlorination and long retention are being used to reduce these bacterial populations in some installations. Most processing plants and feedlots have not dealt effectively with this phase of pollution and much remains to be done.

The dairy industry is not a major industry in the Missouri or Red River Basin. However, there are milk collecting stations and milk processing plants in many small communities. These wastes are frequently discharged to the city sewers. Milk wastes are unusually strong. Even a small plant will generate a waste load greater than all households or other local endeavors of a small community. These wastes can over load a waste treatment plant. The small volume and the watery appearance of the wastes is deceiving and their discharging into the community sewers without allowance for their characteristics is generally accepted practice. Unless consideration of the additional waste loading is included in the treatment plant design, serious operation troubles will develop. These wastes can be treated in conventional plants with domestic wastes if proper allowance is made for their high organic strength.

Volumes of words have been written describing the necessity of fertile soils to meet the demands for food. The soils are aided by the addition of furtilizers and other agri-chemicals. When the soil is eroded and the chemical washed into a stream they both become serious pollutants. Aside from filling stream channels and reservoirs used for water supply and detracting from pleasant appearance, sediment impairs the reoxygenation capacity of waters. Reduced oxygen hurts fish life. Fish population is also further reduced by sediment blanketing fish nests, spawn areas and food supplies.

Aquatic plants need nutrients to flourish, and flourish they will if the plant food is there. A surplus of these plant foods, however, cause the algal "blooms" that frequently result in off-taste and an unpleasant odor in the water. In extreme cases the streams may reach the "green soup" stage of algae and plant growth, and the over growth kills itself, the odor of decaying plants becomes offensive, fish die and there is interference with many water uses.

Little information is now available on the role of sediment as the transporting agent for residues of pesticides and other chemicals in streamflow. Some organic compounds have a known affinity for soil sediment. It can be presupposed that many organic compounds are moved from the fields to the waterways through erosion silt movements.

The potential of land management and use practices for alleviating sediment problems needs study. Economically feasible erosion control techniques are needed not only for the farm and ranch; but also for suburban and industrial areas. The Soil Conservation Service and other agencies of the U.S. Department of Agriculture are actively engaged in trying to control soil losses from our cultivated fields, our pastures and our forests; but no one agency has assumed the lead in attempting to solve suburban and industrial soil erosion problem. This represents a gap in our water pollution control operations.

One should not leave the problem of sediment and associated chemical runoff without a few words regarding another form of agricultural pollution. The pollution from nonfertilizer chemicals used to increase farm production is rising at very great rates. Many of the chemicals used to control animal and insect pests, weeds and fungi are toxic to aquatic life in minute amounts. They may not decompose readily and when they are carried into the streams fish kills often result. Sprays used to control flies in and around barns or feedlots can be carried into streams by surface runoff. Orchard spraying results in residues finding their way into streams. Aerial spraying, can result in chemicals being washed or wind blown into streams. Sprays used to control brush and weeds along road ditches, irrigation ditches and drainage ways are also carried into the waterways.

The Department of Agriculture has recognized the problem and is carrying on extensive research to develop either effective non toxic chemicals or to develop nonchemical means of control. The development of resistant varieties of crops, and changes in farming practices, such as changing to fall plowing which results in high death rates in corn borer populations, are examples of nonchemical controls. Means of attacking insect populations through genetic changes or disturbance of insect reproductive cycles have been sought and good success has been achieved. An example of this type of control is the irradiation of the male screw-worm flies which renders them sterile and since screw-worm flies only mate once and then die, no offspring is generated. This control has been effective in the Southwest. Time precludes delving deeper in this highly interesting area, but it will suffice to say much is being done to keep the use of harmful chemicals to a minimum.

The use of chemical fertilizers such as ammonium sulphate, ammonium nitrate, ammonium phosphate and anhydrous ammonia, has grown at tremendous rates. They are easier to apply than farm waste materials. The fertilizers must be dissolved in water before plants can utilize them. Dissolved, they are not only available to the plant, but they can also be carried into the waterways where the nitrogen and phosphorus can promote algal and other detrimental plant overgrowths causing eutrophication of the streams and lakes. Better means of using chemical fertilizers are being sought. Certainly losing fertilizer to the stream does not increase crop production but results in an actual monetary loss to the farmer and rancher.

Irrigation itself gives rise to another form of agricultural pollution. Of the water diverted from massed supply (reservoirs) and consumptively used, 90 percent is used in irrigation. The irrigation water brought onto a field always carries some dissolved salt. Plants extract water; but most of the salt is excluded by the roots. The water evaporated from the surface is pure water. The salts remain in the soil. In arid climates where nature has left an accumulation of salt in the soil, the application of water will fortify this salt concentration unless the process is countered with excess applications of water to pick up the salt left by the irrigation process and carry it back to the streams or ground water. The salt appearing in the irrigation return flows is that brought in by the irrigation water plus that which may have been naturally present in the soil. In the early years of an irrigation project the salts in the return flow tend to be high. Irrigation takes salts into solution from the soil which had little exposure to water in recent geologic history. So the return flow from an irrigated area is invariably saltier than the incoming water. As a general rule about 25 to 35 percent of the water applied to the soil is returned to the streams or ground water. Assume a salt balance, ignoring the salt normally occurring in the soil, we can see that the concentration of the salt in the return waters will be increased 3 to 4 times. Areas in the Colorado Basin have experienced return flows with concentration increases over 8 times the original concentration. Stream flow composed of largely return flows from irrigated fields, may have a total salinity which will render the water unpalatable to humans, impair its use for animal watering, negate its use in heaters and boilers, and may even prevent further use by downstream irrigators. Some of the fertilizers or pesticides which were applied to the field are dissolved by the water and carried to the streams. The water thus enriched and generally warmed contributes to a more lush growth of vegetation (usually only weeds and algae).

Satisfactory solutions to the problems caused by present irrigation practices are needed. Alternative procedures for handling return drainage flow along some rivers may have to be devised, especially where downstream uses include potable water supplies. A great amount of effort is being expended to develop a solution acceptable to all concerned.

In the past, the pollution control efforts were largely aimed at municipalities and industries. We have made progress in controlling such sources of pollution. The knowledge and technical skills necessary to do this job are now fairly well developed. The big job is the application of this knowledge.

Conversely, the control of pollution from agricultural sources is severely handicapped by lack of knowledge. It has only been in the last decade that the full pollution potential of agricultural operations has been even indirectly appreciated. It must also be realized that the many changes in agricultural activities themselves have added to the pollution potential of this segment of our economy.

In closing, I would like to say to you, as fellow engineers, waste treatment plant operators, city officials, agricultural people and as citizens in general, the problems of alleviating water quality degradation are very great. Agricultural problems are just part of our overall problem; but major part here in the heart of the food producing section of our country. To the design engineers present here tonight I would like to admonish them to learn all they can about the latest developments in advanced waste treatment and to incorporate such knowledge in their new designs. Research does no good unless the results are placed into use, and you as designers are in the key spot to see that the new concepts are put to good use. To the treatment plant operators, you also are going to be called upon to do your part. Some of the new concepts will call for closer control in operation and maintenance. To keep abreast of the new developments you, too, are going to have to upgrade your knowledge by attending short courses, completing correspondence courses and other similar training. To the city officials, industrial and agricultural executives, and citizens, you must be prepared to accept the overall administrative, legal, and financial responsibility required to solve our mutual problem of water quality preservation. As individual citizens we must all add what personal talents we have to help solve this great national problem.

AGRICULTURE AS A SOURCE OF WATER POLLUTION *

by

Eugene T. Jensen **

We Americans -- blessed with masses of undeveloped land and a richness of natural resources -- have just recently awakened to what we were doing to our country and the very resources that have made us rich.

As a result of this new appreciation of our environment, we are beginning to take steps to stop the needless abuses of our resources and to correct the damages that have accrued. One big step has been the recent strengthening of the National legislation dealing with the problem of water pollution.

Let me take just a minute to highlight this legislation; it has increased the commitments and involvements of your Federal government.

-- The Water Resources Research Act of 1964 provides National encouragement and support of State water resources research centers and promotes more adequate water resources research.

-- The Water Quality Act of 1965 and the Clean Water Restoration Act of 1966 commit the national government to working with States and communities to preserve high quality water and clean up dirty water.

-- The Water Resources Planning Act of 1965 provided the Federal vehicle to encourage, promote, and support river basin commissions.

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-- The National Water Commission Act of 1968 set up a National Water Commission to oversee a comprehensive review of national water resource problems and programs.

Additional legislation to control oil pollution and speed construction of critically needed waste treatment plants was a casualty of the closing rush of the past congressional session.

These recently established Federal programs -- along with new State and community programs -- are both a cause and a reflection of the changing approach to water pollution control in America.

In the past, too often we regarded waterways as transport systems for municipal, industrial, and agricultural wastes. Emphasis was on treating waste only to the point that the receiving waters did not become a nuisance.

Now, our efforts are toward maintaining existing water quality where it is high and improving water quality where it is low.

We have, in my opinion, finally realized that high quality water provides many benefits, and we are willing to pay the costs to get the benefits.

Municipalities -- with financial and technical assistance from the Federal and State level -- are moving, if they have not already done so, to treat the wastes generated by the city. In many areas, in fact, municipalities are faced with moving to advanced waste treatment processes over and above the traditional "secondary treatment" if the quality of the water in the stream absorbing the waste is to be maintained in the face of increasing population pressures.

Industry, too, is recognizing that it has not only a social responsibility to clean up its wastewater but that this makes good business sense. Polluted water can become an expense to an industry when the pollution interferes with the industry's needed uses of the same waters.

From the agricultural standpoint -- which is of most concern to you here today -- water pollution still contains a lot of unknowns, both with respect to the effect of the pollution as well as practical ways to avoid it.

Four problems of real significance to farmers and livestock growers are those caused by nutrients, sediments, chemicals, and animal wastes.

Nutrients -- primarily nitrogen, phosphorus, and potassium -- can, when they find their way into surface waters, result in the unwanted growth of nuisance aquatic plants. The unwanted growth -- algae -- affects the taste and odor of water, and can impair the flow in irrigation and drainage ditches. Many of you, I am sure, have seen farm ponds almost completely filled with blue-green algae in the late summer. Such growth can rapidly "kill" a pond.

In urban areas, most of the unwanted nutrients come from municipal waste in the form of raw or inadequately treated sewage. In rural areas, nutrients find their way to ponds and streams as water washes animal waste and commerical fertilizer from pastures, barnyards, and feed lots.

In many respects, the urban problem is an easier one to solve. The nutrient sources are under greater control, and wastewaters can be channeled to treatment facilities where most of the nutrients can be removed before the water is discharged into the receiving stream. Animal waste, fertilizers, of course, are not so easily handled.

Moreover, we have only lately come to realize the significant extent to which animal waste contributes to water pollution. We know that, in some watersheds, domestic animals contribute more to the problem of excessive nutrients than do people. One cow, for example, generates as much waste as 16.4 humans. One hog produces as much waste as two people, and seven chickens can provide a disposal problem equivalent to that created by one person. In total, farm animals in the United States produce ten times as much waste as the human population. And in this country, the animal population increases along with the human population, and is also inclined to increase in even greater proportion as the levels of living rise.

The second major agricultural contribution to water pollution I mentioned was sediments.

Some four billion tons of sediment are washed into tributary streams in the United States each year. The results are costly. The annual bill to the American people now exceeds half a billion dollars. Moreover, water carrying excessive sediment needs extensive treatment to make it fit for municipal and industrial use, and is harmful to fish and other aquatic life. The Nation also suffers the loss of the top soil.

The FWPCA, along with other Department of Interior agencies, the Soil Conservation Service of the Department of Agriculture, and the Corps of Engineers, are tackling this problem. Sediment is one of the factors considered in establishing water quality standards.

The ultimate answer lies in developing and applying sound land management practices to keep sediment out of watercourses, not an impossible task.

Before leaving the sediment problem, however, it is well to note that road construction and urban development often are -- as in the Washington, D. C. area of the Potomac River Basin -- a greater source of sediment per acre than the rural areas.

Agricultural chemicals -- insecticides, herbicides, fungicides, nematocides, rodenticides, growth regulators -- while bringing about tremendous increases in productivity and the quality of agricultural products, also pose some threat to our environment. Many of the products are so new, and have so recently been used on a mass scale that we do not, as yet, know what effects their usage has on the environment or how harmful effects can be prevented. We do know, however, that agricultural chemicals find their way into waters used for home consumption, for livestock, and into ponds and streams. These chemicals in unwanted places can and do kill fish, affect the health of livestock, and otherwise affect water quality.

The FWPCA is sponsoring research to determine the effects of these agricultural chemicals on water quality, and what can be done to control them.

The fourth problem I identified was that caused by animal waste. I have defined some of the problem in speaking of the nutrient load in our waters. Needless to repeat, runoff from animal feedlots is a serious pollution problem affecting both surface and ground waters. The growing practice of confining feeder cattle, dairy cows, hogs, and poultry to barns and lots concentrates the waste and increases the disposal problem. Ten thousand head of cattle on a feedlot produce 260 tons of manure a day. What to do with this manure? If allowed to accumulate, it can cause offensive odors, become a breeding ground for vermin, produce runoff high in nutrients, and may become a source of infectious agents found in streams. No single method of control now in use has proved generally satisfactory in dealing with wastes from confined livestock operations. In some situations controls involving incineration, dehydration, field spreading, composting or lagooning are effective.

Nutrients, sediments, agricultural chemicals, and animal waste. These are the conditions of water pollution that are of direct concern to you. And I'm confident that the agriculturist and livestock grower -- with help from his government -- will find a way to control pollution caused by his agricultural operations. In the final analysis, this is simply a cost of doing business -- the cost of operating and of disposing of waste in such a manner as to not harm the environment.

Actually, I should state that more positively, for I think the real solution is not how to dispose of waste but rather how to use waste so that it is restored to the earth for whatever values it has. Nutrients in water cause troublesome growth. Nutrients in fields can bring profitable growth, as the American farmer so well knows.

Whatever steps are required to control agriculturally generated water pollution, it may comfort you to know that you are not alone. I know of no group of producers, or any particular activity in the United States that does not have some form of water pollution problem it must overcome.

The maintenance of water quality is, indeed, a national problem, a complex interwoven problem, whose total answer will be found only in a total approach. This is the course we are taking in our comprehensive basin-wide planning effort. For purposes of this program, emphasis is placed on developing water quality management programs on a river basin basis. Each basin includes rivers and their tributaries, coastal waters, sounds, estuaries, bays, and lakes plus the lands they drain. For the most part, each can be considered as a separate hydrologic unit.

Effective planning is essential to assure that the large investment in the costs of abating pollution and enhancing water quality in cleaning up of entire river systems will yield optimum returns. Federal water quality management planning is oriented to the development of action programs for meeting current and projected water supply and quality problems on a basin-wide basis. Through the use of scientific engineering, and economic data developed in the basin studies, present problems are defined, future problems are anticipated, and a comprehensive approach is developed for undertaking measures for the immediate clean-up of pollution within a framework that will provide for long-range prevention and control.

The thrust of Federal river basin water quality management planning is to encourage State and local water quality management planning activities and to foster the application of measures which will make a long-term contribution to the enhancement of water quality for public water supply, propagation of fish and aquatic life and wildlife, recreational, agricultural, and other legitimate uses.

An integral factor in cleaning up our waters and keeping them clean is the development of the technical know-how necessary to maintain economic progress while, at the same time, eliminating the accompanying problems of water pollution.

The FWPCA carries out a rather broad and comprehensive research program.

Research grants and contracts are awarded to support basic and applied research projects relating to the causes, control, and prevention of water pollution. These projects are directed toward the discovery and development of new information and technology in the chemical, physical, biological, and social sciences and in engineering. We are also interested in the identification, fate and persistence of pollutants in water and their effects on water uses and treatment processes, non-treatment methods of pollution control, and the ultimate disposal of treated wastes. Grants are awarded to public or private agencies, institutions and to individuals. Demonstration grants and contracts are awarded to assist investigations and studies of an applied nature, and to develop and demonstrate the feasibility of new methods related to the causes, control, and prevention of water pollution. We support projects in the field of water pollution control to public or private agencies, institutions, and individuals which evaluate and apply new information and technology.

The Federal Water Pollution Control Administration also has enforcement authority for the abatement of pollution affecting interstate waters, including coastal waters. The mechanism through which the authority can be used was demonstrated in a recent Federal action taken to abate pollution of Moriches Bay, Long Island. In this case, the wastes produced by one arm of agriculture -- duck farming -- caused damage to another group of farmers -- oystermen. Under the conference procedure, which is specified by the Federal Water Pollution Control Act, representatives of the Federal Water Pollution Control Administration and the State of New York examined all the data having a bearing on pollution of this Bay.

The presence of the duck farms has resulted in the discharge of suspended solids and nutrients to waters of the Bay. These discharges have produced extensive deposits of sludge which has covered the natural bottom and created a habitat unsuitable for the growth and propagation of shellfish and introduced nutrients which have stimulated prolific algal growths.

As a result of the enforcement conference action, waste treatment facilities for the removal of suspended solids and oxygen demanding material have been constructed at all operating duck farms.

Facilities for the removal of nutrients are required to be completed by 1970. This result of the conference shows a corrective action program was agreed upon and remedial action is being taken.

In the overall search for knowledge in water pollution control, agricultural activities have recently begun receiving increased attention. In 1967, FWPCA supported 17 projects, totaling $377,000 with colleges and universities throughout the Nation to study problems and demonstrate solutions varying from the complex effects of pesticides to the management of feedlot wastes in concentrated growing operations

A recently funded project at North Carolina State University here in Raleigh, is researching the pollutional impact of animal growing operations on water quality. This study will provide an engineering basis for assessing water pollution contributions by animal growing and reduce the somewhat careless speculation that has surrounded this waste problem. The first year of the project will deal with swine growing; unconfined grazing operations, as well as confined feedlots, will be evaluated. The evaluation will consider such factors as feed, topography, rainfall, and type of growing facility. If the initial efforts are successful, a second year would study beef and poultry growing operations. The ultimate objective is to enable engineers and scientists to predict water pollution loads from varying types of animal growing operations.

The Research and Development effort is not restricted to study alone. An active program to demonstrate the practicability of improved waste management and treatment is underway. Feeding pens designed for more efficient waste transport have been demonstrated along with improved lagoon systems for more effective treatment. Most important is the development of valid engineering information to enable the animal grower to provide an adequate system at reasonable cost and to know the limits of the system so that he can expand production and waste treatment coincidentally to avoid future pollution problems.

Realizing the demand for more effective treatment, we are supporting research and development in advanced waste treatment and joint treatment projects -- to assist in the development of advanced waste treatment and water purification methods (including the temporary use of new or improved chemical additives which provide substantial immediate improvement in existing treatment processes), or new or improved methods of joint treatment systems for municipal and industrial wastes.

We are also assisting projects which will develop and/or demonstrate new or improved methods controlling discharges into any waters of untreated or inadequately treated sewage or other wastes from sewers which carry stormwater or both stormwater and sewage or other wastes. Research fellowships are provided to increase the number of specialists needed to carry out programs of water pollution control. These fellowships support specialized education and training in a variety of areas relating to water pollution control. These are awarded to qualified individuals on the basis of favorable review of their applications.

In summary, water pollution is a serious problem in the United States and the farmer, along with industry and municipalities, is going to have to operate in such a way as to reduce the effect of waste on water.

I hasten to say that we cannot retreat to the past and cease feedlot operations, stop using pesticides or chemical fertilizers. Rather, we must find and utilize ways to eliminate or minimize water pollution within the context of our current complex agricultural operations.

This will cost money. It's going to cost money to finance the necessary research to give us the knowledge to do the job. And it's going to cost money to apply that knowledge.

But there are no alternatives. We have passed the point where we can expect our waterways to assimilate our untreated wastes. The need for clean and usable water demands that we build the cost of clean water into all of our operations.

Nationally and individually, I think Americans are committed to this course.

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EFFECT OF AGRICULTURE ON WATER QUALITY*

BY

T. R. SMITH**

I am pleased to have this opportunity to represent the Federal Water Pollution Control Administration and to discuss the effect of agriculture on water quality.

We never stop to think that we have a right arm. But if, by accident, it is broken, we are painfully aware that we have this resource and that all is not well with it. When it finally heals and again obeys our every command, we soon lose awareness of this vital resource. Our natural resources are likewise taken for granted. But when our water, for example, develops a foul smell and a bad taste, we become concerned and remain so until the bad qualities are remedied. We may then again take for granted this resource so necessary to life.

Water quality can be affected by many different agents. If not properly treated, municipal sewage and industrial wastes have deleterious effects on water. Similarly, the effects of agricultural activities on water quality is an important factor to consider.

Municipal and industrial wastes can be collected by sewers and given proper treatment at sewage treatment plants before they are discharged into streams. However, it would seem that for agricultural activities, preventative measures would play an important role.

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The main sources of agricultural-associated water pollution in humid regions are: (1) silt from soil erosion; (2) fertilizers, mainly phosphorus and nitrogen compounds; (3) pesticides; and (4) organic wastes from feed lots. In arid regions, irrigation return flows are a problem.

Let's consider the effect each of these sources can have on water quality and suggest some preventative measures. In so doing, reference will be made to the Wabash River Basin. Since the FWPCA made a study of the effect of agriculture on water quality in this area, I will cite some problems existing there.

As it is throughout the Nation, silt resulting from soil erosion is the most damaging form of agricultural pollution in the Wabash River Basin.(1) Seventy-four percent of the land in the basin is crop and pasture land, and only about one-third of it is subject to good soil conservation practices. As a consequence, silt pollutes the basin streams after every storm of any magnitude. Silt also reduces the storage capacity of reservoirs. The reservoir that supplies water for Danville, Illinois, for example, is losing about one percent of its original capacity each year. This reduces the reservoir's life to about 65 years, a short life for a reservoir.(2) Silt increases the treatment costs for municipal and industrial water supplies. It erodes power turbines and pumps, and plugs filters. Silt reduces fish and shellfish populations by blanketing spawning areas and food supplies to the extent that some species may be eliminated. Suspended sediments reduce the amount of light available to green aquatic plants that help maintain dissolved oxygen supplies in water, thus reducing a stream or lake's capacity to assimilate oxygen demanding organic pollutants. Silt pollution is so serious that legislation making it unlawful to permit excessive soil erosion has been suggested.

The deposition of sediment in streams and reservoirs is directly related to soil erosion. To reduce sedimentation to a practical minimum, it is necessary to treat the entire landscape. The best way to achieve this is to first put every acre of land to its best use. The most effective soil conservation practices that are economically feasible should then be applied to every acre of cultivated land, pasture land, and woodland on every farm. This is a time consuming process. In 30 years, soil conservation practices have been applied to approximately 35 percent of the Wabash River Basin. The national picture is substantially the same.(1) It is urgent that this process be speeded up. Farmers can ill afford to lose precious topsoil, and the people downstream can ill afford to have this same topsoil pollute their water supply. The Danville, Illinois reservoir would have had a slower rate of sediment accumulation had a good soil conservation program been maintained on its watershed.

Precipitation intensity and duration and other climatic factors such as temperature strongly influence soil erosion and subsequent stream sediment concentrations. Important environmental factors are topography, soil type, vegetation, and land use. Studies show that three-fourths of the soil loss from experiment station plots at seven locations throughout the United States occurred during four storms a year, and that most of the sediment is carried downstream during flows that occur three or four times a year.(3) This means that 67 to 75 percent of the soil loss must occur during about one percent of a year's time. Methods effective in holding down soil losses during critical storm periods would reduce significantly the sediment load potential.

Land use is the decisive environmental factor in controlling soil erosion and sedimentation. Regardless of soil type, a well managed pasture or forest can effectively control soil erosion. But agricultural production is based largely on field and row crops that require cultivation of the land. On this land, every feasible soil conservation practice should be applied in order to reduce erosion to a practical minimum. Soil type is an important factor governing the severity of erosion on cultivated land. Sloping soils are usually more erosive than nearly level soils. On comparable slopes, highly permeable soils are less erosive than slowly permeable soils. Although much of the cultivated land in the Wabash River Basin is level to gently sloping, most of it ranges from moderately to very slowly permeable. As a consequence, a large part of the cultivated land in this basin is subject to serious soil erosion. Until every feasible soil conservation practice is applied to every acre of the Wabash River Basin, soil erosion and silt pollution and sedimentation of streams and reservoirs will continue to be problems.

Nutrients in runoff water from farm land contribute indirectly to water pollution. In 1964, 1,100,000 tons of fertilizer were applied to 7,370,200 acres of crop land in the Wabash River Basin, a 25 percent increase over fertilizer use ten years earlier. We can expect the use of fertilizer to increase. It must increase if the future demand for food is to be met.

Nitrogen and especially phosphorus carried into streams from farm land are our chief interests. Very low concentrations of these nutrients in water can stimulate nuisance algae blooms which, upon dying and decomposing, impart taste and odor problems to water supplies. To keep the nutrient picture in its proper perspective, I want to point out that municipal and industrial wastes account for an estimated 70 percent of the phosphorus in water, and rural runoff the remaining 30 percent. It is, however, well to remember that municipal and industrial wastes, unlike rural runoff, can be treated to remove 90 to 95% of the phosphorus. When this is accomplished, phosphorus from agriculture will be about five times greater than that from municipalities and industry.

The Evansville Field Station in 1966 and 1967 studied four Upper Wabash Basin streams that drained farm land in watersheds ranging from 21.5 to 92 square miles in size. In these areas there were no industrial wastes or commercial feed lots and only a few small, unsewered villages.

The average soluble phosphorus content of these streams ranged from 0.04 to 0.08 mg/l. Average nitrate nitrogen ranged from 2 to 2.5 mg/l. These concentrations of phosphorus and nitrogen are not great enough to stimulate nuisance algae blooms in these streams but are much more than enough to stimulate nuisance algae blooms in lakes and reservoirs. A concentration of 0.01 mg/l of inorganic phosphorus and 0.3 mg/l of inorganic nitrogen in reservoir water in the spring of the year can be expected to cause nuisance algae blooms.(4) This is much less than the concentration of phosphorus necessary to promote growth of farm crops. Investigators have found that concentrations of phosphorus in solution necessary for optimum growth of different farm crops vary from 0.2 to 0.7 mg/l.(5) This means that farm crops require concentrations of phosphorus 20 to 70 times greater than algae do.

Nutrients in water appear to be related to land use. Present evidence indicates that nutrients in runoff from agricultural areas are higher than the threshold that will stimulate nuisance algae blooms in reservoirs; nutrients in runoff from forest areas are below this threshold.(6) We can generally expect nutrients in runoff from agricultural land to be higher than the threshold that will stimulate nuisance algae blooms in reservoirs and lakes unless preventative measures are taken.

As in controlling soil erosion and sedimentation, application of every feasible soil conservation practice will be necessary to minimize the amount of nutrients carried from farm land into streams.(7) In addition, not more than the optimum amount of fertilizer needed for plant growth should ever be applied. Fertilizers are rarely applied in such amounts at present, but as increasing world population demands more food, more fertilizer will be used to increase crop yields.

Pesticides in water are also of great concern. Pesticides that persist for a long time and are highly toxic are of special concern. Fish kills have been traced to very low concentrations of highly toxic pesticides. In 1964, pesticides were used on 4,061,136 acres of cropland in the Wabash River Basin.(8) This is 19 percent of the basin's area. Crops most commonly treated are corn, small grain, hay, seed crops, vegetables, fruits, and pasture. Cattle, hogs and sheep are treated externally to control insects. The most intensive use of pesticides is on fruit and vegetable crops. Pesticides commonly used are aldrin, amiben, atrazine, carbaryl, diazinon, heptachlor, malathion, trifluralin, and 2, 4-D.

There are several ways by which water may be polluted by the agricultural use of pesticides. Pesticides may enter surface water from: (1) runoff from treated farm land; (2) direct application to water surfaces to control weeds or mosquitoes; (3) drift resulting from aerial applications to farm land; (4) washing and processing of fruits and vegetables; and (5) washing spray equipment and disposal of excess spray material.

We cannot be sure what the cumulative or future long-term effects of pesticides will be. More should be known about the ultimate fate of pesticides following their application to plants, animals, or soils. Some pesticides are known to break down after being in the soil for a short time but are very persistent in water. As they break down, some pesticides form compounds more toxic than the original product.

While agricultural use of pesticides is an important factor in increased crop yields, increasing care must be exercised with their use. Pesticides less toxic to non-target organisms should be substituted and alternate methods of pest control used wherever possible. Rapidly degradable pest control agents should replace non-degradable or slowly degradable agents wherever possible. Pesticides should never be used in excess of the recommended amounts. Excess spray material should never be discharged into surface water and spray equipment should never be washed in surface water. A sound program of soil conservation will lower the amount of pesticides entering surface water from treated farm land.

If these principles are observed, surface water should not be grossly polluted by agricultural pesticides.

Livestock feed lots are a troublesome factor in some areas. The Kansas Board of Health ranks large livestock feed lots as that State's major water pollution problem. Since World War II, cattle feed lots containing up to 10,000 animals have been developed. Ten thousand cattle will produce as much organic waste as a city of 164,000 people.(9) Storms washing wastes from large feed lots into streams have resulted in fish kills and pollution of the water supply of downstream towns. As a result, Kansas now has a state law designed to control feed lot pollution of surface water.

According to the 1964 census, livestock in the Wabash River Basin totaled 1,747,000 cattle, 4,204,000 hogs, 312,500 sheep, 10,409,000 chickens, and 18,600 turkeys. This was livestock on farms and did not include marketed livestock. This livestock population will produce as much organic waste as 38,900,000 people.(9) The basin had a 1960 human population of 3,145,300. Small herds of livestock dispersed on pastures have little effect on water quality. But, improperly treated wastes from large feed lots are a real threat to water quality.

A 1967 canvass of county extension agents in the Wabash River Basin produced the following information: Six hundred and nine feed lots, each holding 200 or more cattle were reported; wastes from 596 cattle feed lots were spread on the land, waste from two were treated in lagoons, and 11 were not spreading or treating wastes. Four hundred and forty-one feed lot, each holding 1,000 or more hogs, were reported. Wastes from 332 hog feed lots were spread on the land, 99 were treated in lagoons, and 10 were not spreading or treating wastes.

Present available information indicates that gross stream pollution from livestock wastes is not occurring in the Wabash River Basin. Pollution from other agricultural sources can be minimized by the application of appropriate soil conservation practices and use of other necessary measures. Animal wastes may be spread on the land or treated in lagoons. In Kansas, livestock wastes treated in lagoons may be used as liquid fertilizer.

In conclusion, since the beginning of widespread cultivation of the land, agriculture has affected water quality. Consequently, it is necessary that agriculturists plan to control pollutional effects of their activities. Fortunately, we have at hand much of the technology needed for the control of agricultural water pollution.

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ECONOMICS OF WATER POLLUTION CONTROL FOR CATTLE FEEDLOT OPERATIONS

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SUMMARY AND CONCLUSIONS

The fed cattle industry has shown a remarkable rate of growth in Texas over the last few years. Fed cattle inventories for the state recorded as of January 1st each year increased 66 percent between 1965 and 1968. The Texas High Plains which has become the center of this rapidly expanding industry experienced a 146 percent increase in cattle inventories in the same three-year period. The exceptional growth of the fed cattle industry on the High Plains can be attributed to a favorable climate, availability of feed grains, adequate supplies of feeder cattle and an adequate transportation network.

The expansion of the fed cattle industry on the High Plains has resulted in the concurrent development of a major water pollution problem. This problem originates in the cumulative build-up of large quantities of organic waste on cattle feedlots in conjunction with sporadic and intense precipitation. The combination of these two factors in turn creates large quantities of heavily polluted feedlot runoff which constitutes a major source of surface water pollution.

The primary objective of this study was to develop and determine the economic feasibility of various methods for controlling or disposing of feedlot runoff. The approach to the problem of water pollution from feedlots used here involved control of runoff by establishing collection basins and subsequently discharging the runoff to one of two disposal areas (open field disposal and playa lake disposal) or alternatively to hold the collected runoff until natural evaporation emptied the system. Secondary sources were used to develop the average relationship between inches of precipitation and resultant runoff. Subsequently, this relationship and 41 years of local rainfall data were used to develop design criteria for a range of sizes of mechanical and evaporative discharge systems. The various design criteria were then applied to three different sizes of model feedlots: (1) 5000 head, (2) 10,000 head, and (3) 25,000 head. Budgets were developed for each feedlot and for each size and type of system and total capital and annual costs were computed.

It was assumed that a part of the cost of operating any particular system would be the penalty imposed by the state water pollution control authorities for overflow. On the basis of current law, this penalty ranges from a minimum of $50 per day to a maximum of $1000 per day.

Three levels of penalty charges were utilized in the analysis of the various budgets. Annual penalty charges for each system were added to annual costs for each system to develop total expected costs for the system. A comparison of these total expected costs yielded an estimate of the minimum cost system. Finally, minimum costs systems providing only minimum overflow protection were compared with higher cost systems providing more adequate overflow protection. Cost differences between the two systems were then evaluated to determine the increase in annual costs associated with additional protection.

An evaluation of total expected costs for mechanical discharge systems utilizing the open field disposal technique indicated that 5"-.4", 6"-.2", 5"-.2" systems achieved minimum costs for the 5000, 10,000 and 25,000 head model feedlots respectively at the $1000/day penalty level.[1] Total expected costs at this penalty level amounted to $1011, $1596 and $3125 for the 5000, 10,000 and 25,000 head model feedlots respectively. Expected overflows in turn amounted to 4 overflows for the 5000 and 10,000 head model feedlots or one overflow every 10 years, and 8 overflows for the 25,000 head model feedlot, one overflow every 5 years.

The playa lake disposal modification achieved slightly lower total expected costs than the open field disposal modification for the 25,000 head model feedlot for the same level of protection and at the same penalty level. Differences in total expected costs between these two modifications were relatively small ($304) and in any case were somewhat dependent on the distance pumped to the playa lake disposal area. Longer distances than those assumed by this study would necessarily incur higher costs.

Costs of all mechanical discharge modifications were compared with costs incurred by the less complex evaporative discharge system. This latter system achieved minimum costs for the 5000, 10,000 and 25,000 head model feedlots when constructed with a 16" capacity collection basin and budgeted at the $1000 per day penalty level. The number of overflows from this minimum cost evaporative discharge system amounted to 7 overflows in the 41 year period or approximately one overflow every 6 years. In general, evaporative discharge systems were considered inferior to their mechanical discharge counterparts because of the lower degree of protection provided and the rather extensive land requirements for construction of the collection basin.

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[1] System sizes are described in terms of the number of inches of rainfall equivalent held by the collection basin at capacity and the rate of discharge of the system in inches of rainfall equivalent per day. Thus, a 5"-.2" system will hold a maximum of 5" of rainfall equivalent in the collection basin and will discharge at the rate of .2" of rainfall equivalent per day.

A city treatment plant disposal modification was considered and subsequently eliminated as a possible runoff control alternative for the model feedlots. The analysis indicated that a 2"-.2" system in association with a 5000 head feedlot would incur treatment costs of approximately $25,000 per year. Similarly a 5"-.4" system providing a higher degree of overflow protection in association with a 25,000 head feedlot would incur treatment costs of approximately $1,080,000 per year. The analysis of the city treatment plant disposal modification is not included in the text of this report.

INTRODUCTION

Cattle feedlot operations in Texas have experienced a phenomenal rate of growth over the last few years such that the state has moved into a position of primary importance in the fed cattle industry. Texas feedlot inventories as of January 1, 1965, amounted to 488,000 head. This figure had increased to 810,000 head by January 1, 1968, or an increase of 66 percent in the three-year period. In the same period feedlot inventories in the 32 major cattle feeding states increased from 9,348,000 head to 11,297,000 head or an increase of 12 percent. Increases in fed cattle inventories in Texas made up 17 percent of the 1,949,000 head increase in inventories indicated for the 32 major cattle feeding states.

The thirty-three county High Plains area has become the center of this rapidly expanding industry in Texas. Fed cattle inventories in this area increased by 146 percent in the period January 1, 1965, to January 1, 1968. In 1967 in excess of 1.5 million head were fed out in the High Plains area. Preliminary estimates indicate that total fed cattle output will amount to 1.7 million head in 1968, and that the current expansion phase of the industry may peak out by 1970 at approximately 2.0 million head annually.

The Problem

The expansion of the fed cattle industry in Texas has resulted in the concurrent development of a number of management problems dealing with solid and liquid waste that have broad social and economic implications. These problems are attributable to the high concentration and large number of animal units required for efficient feedlot operations. The most acute of these problems from the standpoint of feedlot operators is the potential of the feedlot as a source of water pollution. Only a few years ago, designers of cattle feedlots selected feedlot sites based primarily on two criteria: drainage and accessibility. Consideration of the drainage factor practically insured location on the nearest draw which in the absence of positive control measures made ultimate pollution of the surface water course a certainty. Today, a change in public awareness of pollution problems and a concurrent development in the attitudes and responsibilities of public agencies charged with enforcing anti-pollution laws have created an entirely new socio-political environment. These latter factors coupled with rapid expansion of the industry and intensification of the problem have created a situation wherein prevention of water pollution has become a matter of serious concern to the fed cattle industry.

The environmental characteristics of the High Plains area contribute in a large degree to the magnitude of the water pollution problem. This area has a semi-arid climate with 15-20 inches of annual rainfall. Evaporation rates are high in summer and the limited rainfall received comes in sporadic bursts over relatively short time periods. Pollution problems are intensified by the intermittent character of their occurrence following heavy rains. The resultant polluted runoff from one acre of feedlot can equal the sewage load of a community of 2730 people. Consequently, unless controlled this runoff will in time gravitate to the nearest public water course for which it constitutes a major pollution source.

Objectives

The general objective of this study was to develop and determine the economic feasibility of various procedures or methods for controlling and disposing of feedlot runoff. More specifically, the objectives were:

1. To determine the quantity and quality of runoff from representative feedlots under High Plains conditions.

2. To design procedures for controlling and disposing of runoff water from representative feedlots on the Texas High Plains.

3. To determine the physical and engineering requirements for alternative methods or systems of controlling and disposing of runoff water from representative feedlots.

4. To evaluate the economic feasibility of alternative methods or systems of controlling and disposing of runoff water from representative feedlots.

5. To develop and provide baseline data which will enable feedlot operators to select the most appropriate control and disposal system.

QUANTITY AND QUALITY OF RUNOFF

Characteristics of Runoff

A determination of BOD from simulated feedlot runoff studies at Texas Technological College indicated a range of 500 Mg/l to 3300 Mg/l with a mean of 1687.5 Mg per litter.[2] In Kansas studies, Smith and Miner found that runoff water from cattle feedlots created a waste slug of polluted water in an adjacent stream.[3] The BOD of the polluted slug was calculated at 345 Mg/l. This compares to a dry weather average of 2.6 Mg/l BOD for the same stream.

Quantity of Runoff

The magnitude of the pollution problem, as measured by the volume of runoff which must be controlled, is a function of the amount of precipitation falling on the lot and that fraction which will become runoff. The quantity of runoff will depend on the quantity of waste on the lot and its physical condition. When feedlots have a heavy dry cover of manure, considerable quantities of precipitation will be absorbed before runoff occurs. In contrast, for saturated lots very little precipitation falls before runoff begins.

The Kansas runoff studies provided data on the average annual relationship between precipitation and runoff.[4] Utilizing these data an equation (1) was developed to determine inches of runoff for given inches of precipitation as follows:

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[2] BOD (Biological Oxygen Demand) is defined as that quantity of oxygen utilized in the biological oxidation of organic matter during an incubation period of five days at 20 degrees centigrade.

[3] Stanley M. Smith and J. Ronald Miner, Stream Pollution From Feedlot Runoff, Environmental Health Service, Bulletin No. 2-1 (Topeka, Kansas: January 1964).

[4] Letter from Dr. R. I. Lipper, Department of Agriculture Engineering, Kansas State University, August 1, 1967.

$$K = -0.3819 + 0.8732\ P \qquad (1)$$

where: K = inches of runoff

P = precipitation in inches

This equation, determined by the method of least squares, explains 91.2 percent of the variation in runoff observed in the Kansas studies. The volume of runoff was determined by the following equation:

$$G = \frac{K}{12} \times A \times 43560 \times 7.481$$

$$= K \times A \times 27156$$

G = gallons of runoff water

A = acres of feedlot (pens and roads)

43560 = square feet per acre

7.481 = gallons of water in a cubic foot

Collection Systems

Design criteria for collection basins which will minimize waste collection costs are the ultimate basis of low cost pollution control. Runoff water in this study was limited to that precipitation falling directly on the feedlot to minimize collection basin size. Accordingly, foreign water was excluded by construction of diversion works on the perimeters of the feedlot.

Collection Basin Capacity

The required holding capacity for any runoff collection system is a function of the quantity and frequency of precipitation, the total feedlot acreage contributing to runoff, the physical character of the surface of the feedlot, and finally, the acceptable degree of tolerance with respect to periodic overflow. With respect to the latter characteristic, total protection, although physically feasible, can be achieved only at a relatively high cost. The acceptable degree of tolerance in any case will tend to vary with individual management's attitude toward risk of overflow. Consequently, in developing design criteria for model feedlot collection systems, due recognition should be given to the existence of varying management attitudes ranging from relatively low risk acceptance to high risk acceptance. A method of recognizing this variability is to select a series of capacities which would incur a relatively high frequency of overflow ranging upward to capacities which would incur a relatively low frequency of overflow.

Design capacities for the development of runoff water collection systems in this study were based on rainfall data covering a 41 year period.[5] Data covering a 42 year period were examined, however, the year 1941 was excluded since rainfall received in that year exceeded more than twice the annual average rainfall. This latter occurrence represents a fortuitous event which would fall in the same category of natural happenings such as earthquakes and other rarely occurring phenomena for which protection cannot be provided.

Rainfall data and equation 1 were used to compute the quantity of runoff flowing into each system, and given the size of each system, the resultant probability of overflow. Only rainfall amounts equal to or in excess of .44" were considered subject to runoff. The limiting quantity of .44" was determined from equation 1. That is, when K (runoff in inches) is equal to zero, P (precipitation in inches) is equal to .44 inches.

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[5] Rainfall data supplied by United States Government Weather Bureau at Lubbock, Texas.

Collection basin designs were formulated on the basis of two distinct types of runoff control technology. The technologies and the resultant systems were termed "mechanical discharge systems," and "evaporative discharge systems." The former system involved discharge of accumulated runoff in the collection basin by pumping to one of two ultimate disposal areas. Design of the latter system, the evaporative discharge system, contemplated discharge of accumulated runoff in the collection basin by complete evaporation over time.

Mechanical discharge systems were designed to hold the runoff equivalent of either 2, 3, 4, 5, or 6 inches of cumulative precipitation. In contrast, evaporative discharge systems were designed to hold the runoff equivalent of 12, 13, 14, 15, or 16 inches of cumulative precipitation. Collection basins for mechanical discharge systems have relatively small capacities as determined by the difference between the expected cumulative runoff and the discharge capacity of the pump. Design criteria for these systems assumed no evaporation losses due to shortness of the holding period. Similarly, design criteria for the evaporative discharge systems made no provision for seepage losses since it was assumed the collection basin would be self-sealing.

A measure of the degree of runoff protection afforded by either a mechanical or evaporative discharge system of a specific capacity is the number of overflows. Smaller capacity systems of either type will have a greater frequency of overflow than larger ones. Given the size of the system, frequency of overflow can be determined through analysis of historical rainfall data, assuming specific discharge and evaporation rates for the mechanical and evaporative discharge systems respectively.

Number of Overflows - Mechanical Discharge Systems

Three specific discharge rates of 0.2, 0.4, and 0.6 inches of rainfall equivalent per day were selected for each of the five sizes of collection basin. Overflow calculations were based on the holding capacity of the collection basin in terms of rainfall equivalents. Similarly, discharge rates are also stated in terms of rainfall equivalents though at a latter stage, pumping costs were computed in terms of runoff equivalent or runoff actually discharged. For example, a 3-inch system has an actual holding capacity of only 2.2 inches of runoff since .8 inches will be absorbed by the feedlot (equation 1). To simplify the overflow calculations, all systems including discharge capacities were stated in terms of rainfall equivalents.

The procedure followed in determining the number of overflows for mechanical discharge systems is illustrated in Table 1. On June 6, rain fell in the amount of .06 inches. Since this figure is less than .44 inches, no runoff occurred, hence, it was not added to the system. On June 7, rain fell in the amount of .82 inches. This latter figure is greater than .44 inches, consequently, it was added to the collection basin. The same procedure was followed for the remainder of the period; that is, rainfall amounts of less than .44 inches were not counted, and rainfall in excess of .44 inches was added to the quantity in the collection basin up to a cumulative total rainfall equivalent of 3.00 inches after which overflow would occur. Table 1 indicates that on June 10th, the collection basin contained 3.40 inches of rainfall equivalent.

Since the capacity of the system is 3.00 inches of rainfall equivalent, then .40 inches constituted overflow. The data for the 10th of June, were subsequently adjusted to balance the system at a capacity of 3.00 inches, and an entry made indicating that overflow had occurred. The same procedure was followed for the remaining system sizes at three selected discharge rates. Table 2 indicates the size of the system, the applicable discharge rate, and the number of overflows which would have occurred in the 41 year period for which hydrological data were available.

TABLE 1

OVERFLOW CALCULATIONS FOR JUNE, 1949,

3 INCH MECHANICAL DISCHARGE SYSTEM, .2 INCH DISCHARGE RATE,

TEXAS HIGH PLAINS

Day of Month	Rainfall Inches	Discharge In Inches/24 hrs.	Balance Inches in Basin
		(Rainfall Equivalent)	
6	.06	0	0
7	.82	0	.82
8	.58	-.2	1.20
9	1.48	-.2	2.48
10	1.12	-.2	3.40
	Overflow .4"	Corrected Balance	3.00
11	0	-.2	2.80
12	0	-.2	2.60
13	.40	-.2	2.40

The average number of gallons of water pumped from each collection basin was determined simultaneously with number of overflows. Gallons of water discharged were determined by summing the total inches of rainfall that occurred in amounts of over .44 inches, subtracting the total

2.4

inches of overflow from the system, and dividing by the number of years, 41. In other words, if T is the sum of the quantities of rainfall in inches occurring in amounts in excess of .44 inches, and t is the sum of the rainfall equivalents in inches that overflowed the collection basin, then $\frac{T-t}{41}$ = average rainfall equivalents subjected to discharge (3)

TABLE 2

NUMBER OF OVERFLOWS, MECHANICAL DISCHARGE SYSTEMS,
FIVE SELECTED SYSTEM SIZES, THREE DISCHARGE RATES,
41 YEAR PERIOD (1926-1967)[a], TEXAS HIGH PLAINS

System Size in Rainfall Equivalent Inches	Discharge Rate Rainfall Equivalent Inches/24 hr	Frequency of Overflow
2	.2	75
	.4	59
	.6	50
3	.2	36
	.4	29
	.6	19
4	.2	17
	.4	11
	.6	8
5	.2	8
	.4	4
	.6	4
6	.2	4
	.4	4
	.6	3

[a] The year 1941 was excluded.

Rainfall equivalents removed from the system by pumping are converted to inches of runoff by equation 1 ($K = -3819 + 0.8732\ P$) and to gallons of runoff by equation 2 (G = R x A x 27156).

The following example indicates the method utilized in computing the quantity of water discharged from each system given the quantity of overflow which occurred. The value of T for all 2" systems at a .2" discharge rate as derived from the 41 years of rainfall data amounted to 483.44 inches of rainfall equivalent. In the same 41 year period, a 2" system discharging from the collection basin at the rate of .2 inches of rainfall equivalent per 24 hours would have a total overflow t equal to 66.59 inches of rainfall equivalent. Therefore:

$$\frac{T-t}{41} = \frac{483.44 - 66.59}{41} = 10.17$$ inches of rainfall equivalent to be removed from the system each year. Inches of rainfall equivalent were converted to runoff by equation 1.

$$K = -0.3819 + 0.8732\ (10.17)$$

$$K = 8.50 \text{ annual inches of runoff}$$

Gallons of runoff per acre were subsequently determined by:

$$\begin{aligned} \text{Gallons of Runoff per acre} &= Q = R \times A \times 27156 \\ &= 8.5 \times 1 \times 27156 \\ &= 230{,}826 \end{aligned}$$

Number of Overflows - Evaporative Discharge Systems

The cumulative amount of runoff retained in a collection basin in any time period is a function of the amount of rainfall, the rate of evaporation, the design depth of the system, and the number of overflows. This latter quantity, number of overflows, is a necessary element in determining the appropriate size of the optimum system. Consequently, given the expected precipitation rates, evaporation rates and design depth, the number of overflows may be estimated.

Evaporation from the collection basins of evaporative discharge systems was assumed to take place at the same rate as evaporation from playa lakes on the High Plains. Data on average evaporation rates in feet for each month are given in Table 3.

TABLE 3

EVAPORATION RATES BY MONTHS FROM PLAYA LAKES, TEXAS HIGH PLAINS*

Month	Evaporation Per Month (feet)
January	.160
February	.233
March	.460
April	.617
May	.716
June	.845
July	.883
August	.801
September	.625
October	.493
November	.295
December	.202
Total	6.330

*Data on daily evaporation rates presented in "Hydrology, Conservation, and Management of Runoff Water in Playa Lakes on the Southern High Plains," Conservation Report No. 8, (Agricultural Research Service, USDA) Washington, D. C., August 1966, p. 12.

Evaporative discharge systems were assumed to have reached full capacity when the collection system was filled to a depth of eight feet. Preliminary estimates indicated that systems of less than eight feet in depth appeared to require an excessive quantity of land and systems greater than eight feet experienced a high rate of overflow. This latter phenomena was the result of the relationship between surface area and evaporation rates. That is, deeper systems with smaller surface areas had less evaporation, hence, large accumulations of runoff and more frequent overflows. The eight foot limitation was thus selected as a practical alternative to either deeper or more shallow systems. Expected precipitation rates were determined on the basis of the analysis of rainfall data for Lubbock, Texas. To determine the number of overflows from any given evaporative discharge system, evaporation rates expressed in feet in Table 3 must be converted to evaporation expressed in rainfall equivalent inches. This change in units of expression may be accomplished by the following equation.

$$X_i = \frac{S\,Y_i}{8}, \quad i = 1, 2, \ldots, 12$$

where: X_i = evaporation expressed in inches of rainfall equivalent for the month i

Y_i = evaporation in feet for the month i

S = size of the collection basin in rainfall equivalent inches

8' = depth of water in the collection basin when filled to capacity

For example, the evaporation rate expressed in rainfall equivalent inches for the month of July for the 15" collection basin was calculated as follows:

$$X_7 = \frac{(.883)(15)}{8}$$

$$X_7 = 1.66$$

Therefore, a 15" system will experience a loss through evaporation of 1.66 inches of rainfall equivalent. To illustrate the example further, suppose that at the beginning of July, a 15" collection basin contained 5 inches of rainfall equivalent. Assume that during the month of July, two inches of rainfall occurred, and that this rainfall was all subject to runoff. Then the balance in rainfall equivalent inches contained in the collection basin at the beginning of August would be 5.34" (5+2-1.66 = 5.34). The range of sizes for evaporative discharge systems considered in this study and the number of respective overflows for the 41 year period are given in Table 4.

TABLE 4

NUMBER OF OVERFLOWS, EVAPORATIVE DISCHARGE SYSTEMS,
FIVE SELECTED SYSTEM SIZES, 41 YEAR PERIOD (1926-1967)[a],
TEXAS HIGH PLAINS

System Size In Rainfall Equivalent Inches	Number of Overflows
12	111
13	83
14	58
15	16
16	7

[a] The year 1941 was excluded.

MODEL FEEDLOT ASSUMPTIONS

The relevant cost data were developed through use of a synthetic model analysis which gave tangible form to the various design criteria. The synthetic model analysis began with various assumptions such as feedlot size, cattle density, total feedlot area and slope. Next, a specific control and disposal system was selected, the necessary input-output relationships developed and subsequently costs were determined for each system. Three sizes of feedlots; 5,000 head, 10,000 head, and 25,000 head were considered in the analysis.

Mechanical discharge systems were limited to discharging from any of five selected capacity collection basins to one of two alternative disposal areas: (a) an open field and (b) a playa lake. These disposal techniques are currently used by a number of feedlots on the High Plains. Technique (b), although a relatively efficient method of disposing of runoff water from a physical standpoint, is rather inflexible since it depends on prior location of the feedlot in proximity to a playa lake of sufficient size to efficiently absorb the pollutant. Technique (a), open land disposal, appears to furnish the most readily utilizable alternative for any existing lot.

Specific assumptions relative to the physical environment of the model or representative feedlots are enumerated as follows:

1. Hydrological data used in the study is specific for Lubbock County, Texas area. Similarly, the various cost coefficients such as labor rates, tax rates and construction and equipment costs are specific for the Lubbock County area.

2. The model feedlots are designed in the form of a square on land

with an assumed average slope of 5 percent. The associated runoff control facilities are also constructed on land with a slope of 5 percent.

3. Land above the feedlot elevations utilized for parking, feed storage, administration, shipping, receiving or other agricultural use is assumed to be equivalent to 30 percent of the total area of the model feedlots. The total volume of runoff from this area will depend on total acreage, soil permeability, and vegetative cover. It was assumed that 50 percent of the precipitation falling on this area will become runoff and that this runoff water can be diverted around the feedlot.

4. Cattle density was stipulated at 150 sq. ft. of pen space and 1.5 feet of bunk space per animal with a total of 200 animals per pen. Roads and alleys or service ways were assumed to be equivalent in area to 20 percent of the total pen space. Total acreage (pens, roads, and alleys) amounted to 20, 40, and 100 acres for the 5,000, 10,000, and 25,000 head model feedlots, respectively.

5. It was assumed that there was sufficient land below the feedlot to construct both the mechanical and evaporative collection basins.

6. It was assumed that for disposal technique (a), the open land disposal modification, a sufficient acreage of open land adjacent to the model lots was available and could be used as a disposal facility. Table 5 indicates the assumed elevations and distances from the collection facility to the center of the open field for each of the model feedlots.

Disposal technique (b), the playa lake disposal modification, requires the availability of a lake of sufficient size for disposal of the total amount of runoff from each of the model feedlots. It was assumed that this lake was of sufficient size that the addition of runoff would not significantly alter the quality of the lake water for irrigation purposes. Distance to the lake was stipulated at 2,500 feet at zero difference in elevation from the collection point.

TABLE 5

ASSUMED DIFFERENCE IN ELEVATIONS AND DISTANCES FROM THE COLLECTION BASIN TO THE CENTER OF THE OPEN FIELD DISPOSAL FACILITY

Lot Size (Head)	5,000	10,000	25,000
Elevation (ft.)	35	43	62
Distance (ft.)	700	860	1244

PHYSICAL SPECIFICATIONS AND COST COEFFICIENTS

The model feedlot runoff control system consists of diversion terraces, waterways, a collection basin, runoff disposal area and associated mechanical equipment for facilitating discharge and disposal of the pollutant. These various components may be divided into two groups, land improvements and mechanical equipment. Specification of the physical requirements and cost determinations for evaporative discharge systems are limited to land improvements. The more complex mechanical discharge systems in contrast require specification and costing of both land improvements and mechanical equipment components.

Land Improvement Components

Diversion Terraces and Waterways

The basic runoff control system for the model feedlots specified the construction of appropriately sized terraces and waterways around the perimeter of each lot in order to minimize the amount of runoff which must be controlled. These facilities were designed to control the maximum rainfall which might be expected to occur in a one hour period with a return period of 25 years. The maximum 25 year return rainfall per one hour period for Lubbock County amounted to 2.65 inches.[6] Figure 1 is an illustration of two model feedlots and their associated runoff control facilities.

Costs for these components will remain constant for each selected

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[6] U. S. Department of Commerce, Weather Bureau, Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 years. (Washington, D. C.: Government Printing Offices, 1961), p. 101.

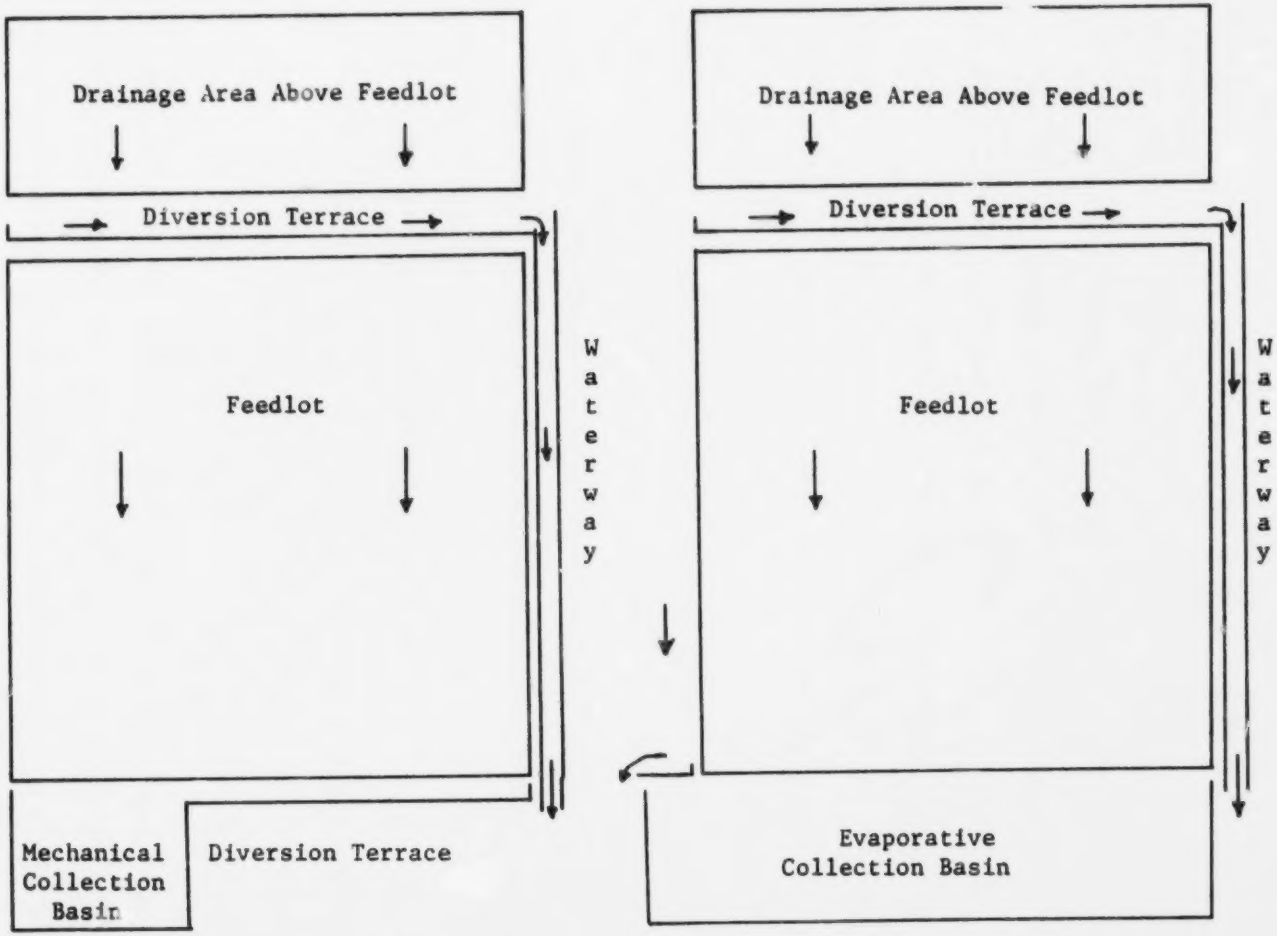
Drainage Area Above Feedlot
Diversion Terrace
Feedlot
Waterway
Mechanical Collection Basin
Diversion Terrace
Drainage Area Above Feedlot
Diversion Terrace
Feedlot
Waterway
Evaporative Collection Basin

Figure 1.--Sketch of General Layout For Two Feedlots and Their Pollution Control Facilities.

disposal system since size of the facility is based on maximum expected rainfall, hence, will not vary with the method of collection or disposal.

Collection Basins

Construction specifications for all systems called for an operational depth of 8 feet for the collection basin plus an additional allowance of 10 percent added depth to the mechanical discharge systems and 25 percent added length to the evaporative discharge systems. These latter modifications to the basic design provided additional capacity to hold suspended organic solids which were washed into the collection basin plus an allowance for precipitation falling directly on the basin surface.

Capital or investment costs for all collection systems include the cost of construction and the cost of land utilized by the pollution control facilities (See Appendix A, Tables 1 and 2 for costs). If ample land is not available, it must be purchased or if available, it must be diverted from its present use. Either situation represents an additional cost to the feedlot. Land costs in this study were specified at $500 per acre on the basis of conversations with local feedlot operators (See Appendix A, Tables 3, 4, and 5 for land requirements).

Open Field Disposal Areas

Specifications and costs of diversion terraces, waterways and collection basins are common to all systems regardless of the ultimate disposal of the runoff. This latter function, runoff disposal, however, requires an additional amount of land for the open field disposal modification which is in excess of that required by the playa lake disposal system.

The amount of land required for the open land disposal modification is a function of the gallons pumped per minute, the absorption capacity of the soil and the efficiency of the sprinkler system[7] (See Table 7, page 25). Technical sources indicated that light sandy soils have a percolation rate of 0.75 to 0.5 inches per hour and medium soils, a percolation rate of 0.5 to 0.25 inches per hour.[8] An absorption rate of 0.5 inches per hour was assumed for the model feedlot facilities on the basis that this rate should constitute a reasonable estimate of the water absorption capacity of soil in the High Plains area. Specifications for the sprinkler system were based on manufacturers recommendations which indicated that 70 percent would constitute a practical estimate of sprinkler efficiency under High Plains conditions. Acreage requirements for the open field disposal modification were computed as follows: Letting $K = 0.5$, then A was determined from equation 2 as

$$G = 0.5 \times A \times 27156$$

$$A = \frac{G'}{13578} \qquad (5)$$

where: $G' = \text{gpm} \times 60 \times .70$

The procedure is best illustrated by the following example. A 5000 head feedlot with a 3 inch collection basin capacity and a .2 inch per day discharge rate would require approximately .3 acres of land for pollutant disposal. This land requirement is arrived at by

$$G' = 56 \times 60 \times .70$$

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[7] Efficiency of a sprinkler system is calculated on the basis of that quantity of water which percolates into the soil compared to total water emitted by the sprinkler.

[8] Rainy Sprinkler Sales, Division of L. R. Nelson Mfg. Co., Peoria, Illinois, Catalog 67-A, 1967.

$$G' = 2352$$

$$A = \frac{2352}{13578}$$

$$A = .17$$

Given the calculated values, each requirement was increased by a 50 percent safety factor and rounded upward to the nearest tenth of an acre. Land for pollutant disposal was priced at $500 per acre and total land component costs were expanded to include the establishment of a vegetative cover (Bermuda grass) on the disposal area.

Mechanical Equipment

Design criteria for mechanical discharge systems envisaged two alternative final disposal areas for runoff. These areas were (1) open field disposal and (2) playa lake disposal. The basic disposal system consisted of pumps, motors, and auxiliary piping. The open field disposal modification also included sprinklers for final distribution. All pumps were centrifical types with automatic controls. Pipe sizes and weights were selected to meet capacity requirements for each modification with some variation to accommodate the higher pressures required for the sprinklered open field modification (See Table 6). Evaporation from the collection basin was not considered a factor in view of the relatively short holding period prior to disposal.

Runoff discharge rates are expressed in gallons per minute and were calculated as follows:

$$GPM = \frac{G}{DM} \qquad (6)$$

where: GPM = gallons per minute

G = capacity of the system in gallons

D = days required for pumping when filled to capacity

M = minutes per day

TABLE 6

FACTORS DETERMINING SIZE OF PUMPING EQUIPMENT, ALTERNATIVE DISPOSAL MODIFICATIONS, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Alternative Disposal Destinations for Pollutant	Distance Runoff Water is Pumped in feet	Difference In Elevation In Feet	Type of Outlet
Playa Lake	2500	0	Open flow pipe
Open Field[a]			
5,000 head	700	35.0	Sprinkler System
10,000 head	860	43.0	
25,000 head	1244	62.2	

[a] It was assumed that the disposal area had the same slope as the feedlot and that sprinkler deliveries to the disposal area would be carried to the center of the disposal area. Consequently, as the disposal area increases in size, the elevation of the disposal point above the collection basin increases.

The capacity of the collection basin in gallons (G) of runoff or pollutant was determined by equation 2 ($G = R \times A \times 27156$). For example, a 3 inch rainfall equivalent collection basin will hold 2.2377 inches of runoff when filled to capacity. Accordingly, this collection basin will require 15 days to empty at the specified discharge rate of .2 inches of rainfall equivalent per day ($3'' \div .2'' = 15$). Gallons pumped per minute are calculated as follows:

$$GPM = \frac{1,215,340}{(15)\ (1440)} = 56.27$$

Equipment selections were made on the basis of the above requirements according to manufacturers recommendations.

Investment Cost Comparisons

Total investment costs for mechanical discharge systems consist of facility construction cost, land cost, and mechanical equipment cost (Pumping equipment) (See Table 8). The open field disposal modification required the least total investment with the playa lake modification second in total investment requirements for selected system sizes and discharge rates for the 5,000 head model feedlot. The same pattern was observed for the 10,000 head model feedlot with the exception of those systems discharging at .6 inches per day. The playa lake disposal modification discharging at .6 inches per day required the least total investment cost with the open field disposal modification second in total investment requirements. The playa lake disposal modification required the smallest total investment cost with the open field disposal modification second for all system sizes for the 25,000 head model feedlot. Table 9 summarizes the order of these investment costs.

Total investment costs for evaporative discharge systems include only land cost and facility construction cost (See Table 10).

Comparisons of the evaporative and mechanical discharge systems were made by comparing total investment cost among those systems which have approximately the same frequency of overflow (See Table 11). Total investment costs for evaporative discharge systems exceeded total investment costs for mechanical discharge systems providing a comparable level of protection for the 25,000 head model feedlot. Similarly, total investment costs for evaporative discharge systems providing a comparable level of protection to mechanical discharge systems (open field and playa lake modifications) exceeded total investment costs for the latter systems

TABLE 7

COLLECTION BASIN CAPACITY AND TIME REQUIREMENTS FOR DISCHARGE, ALTERNATIVE SYSTEM SIZES, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS

System Size in Rainfall Equivalent Inches		System Capacity			Required Pumping Time	Discharge Rate		
Basin Capacity	Discharge Rate/24 hrs.	5000 Head (20 acres)	10,000 Head (40 acres)	25,000 Head (100 acres)		5000 Head (20 ac)	10,000 Head (40 ac)	25,000 Head (100 ac)
		(Gallons)	(Gallons)	(Gallons)	(Days)	(GPM)	(GPM)	(GPM)
2	.2	741,090	1,482,181	3,705,444	10	51	103	257
	.4				5	103	206	515
	.6				3	155	309	773
3	.2	1,215,341	2,430,682	6,076,704	15	56	113	281
	.4				8	113	225	563
	.6				5	169	338	844
4	.2	1,689,591	3,379,190	8,447,972	20	59	117	293
	.4				10	117	244	587
	.6				7	176	352	880
5	.2	2,165,450	4,327,691	10,819,232	25	60	120	301
	.4				13	120	240	601
	.6				8	181	361	902
6	.2	2,638,100	5,276,200	13,190,499	30	61	122	305
	.4				15	122	244	611
	.6				10	183	366	916

TABLE 8

TOTAL INVESTMENT COSTS, SELECTED SIZES AND TYPES OF MECHANICAL DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Open Field Disposal			Playa Lake Disposal		
Basin Capacity	Discharge Rate/24 hr	5000 Head	10,000 Head	25,000 Head	5000 Head	10,000 Head	25,000 Head
		----- Dollars -----					
2	.2	5235	6783	11950	6125	7379	11358
	.4	5491	7648	14183	6239	7879	11941
	.6	5936	8146	16533	6739	7962	12827
3	.2	5643	7691	14173	6546	8249	13518
	.4	5913	8571	16676	6647	8749	13966
	.6	6456	9147	19181	7147	8911	14938
4	.2	6052	8482	16193	6954	8963	15427
	.4	6399	9362	18702	7055	9497	15875
	.6	6864	10368	21750	7555	10001	16847
5	.2	6460	9346	18198	7363	9827	17432
	.4	6807	10226	20824	7464	10361	17880
	.6	7272	11234	23878	7964	10865	18852
6	.2	7308	10211	20201	8211	10692	19435
	.4	7655	11091	22905	8312	11226	19883
	.6	8198	12177	26004	8812	11730	20855

TABLE 9

SUMMARY OF THE ORDER OF TOTAL INVESTMENT COST, MECHANICAL DISCHARGE SYSTEMS, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Feedlot Size	Alternative Systems (OF-open field, PL-playa lake)
5,000 Head (all discharge rates	OF<PL[a]
10,000 head (.2" & .4" discharge rate)	OF<PL
10,000 head (.6" discharge rate)	PL<OF
25,000 head (all discharge rates)	PL<OF

[a] The notation < is read OF less than PL.

TABLE 10

TOTAL INVESTMENT COST, SELECTED SYSTEM SIZE, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size In Rainfall Equivalent Inches	Feedlot Size (Head)		
	5,000	10,000	25,000
	Dollars		
12	6872	12118	28382
13	7318	13003	30592
14	7732	13940	32776
15	8149	14795	35042
16	8600	15681	37257

TABLE 11

MECHANICAL AND EVAPORATIVE DISCHARGE SYSTEMS COMPARED BY APPROXIMATE NUMBER OF OVERFLOWS, BY SYSTEM SIZE, TEXAS HIGH PLAINS

Mechanical			Evaporative	
System Size in Rainfall Equivalent Inches		Estimated Frequency of Overflow (41 year period)	System Size in Rainfall Equivalent Inches	Estimated Frequency of Overflow (41 year period)
Basin Capacity	Discharge Rate/24 hrs			
2	.2	75	13	83
2	.4	59	14	57
4	.2	17	15	16
5	.2	8	16	7

TABLE 12

SUMMARY OF THE ORDER OF TOTAL INVESTMENT COSTS, MECHANICAL AND EVAPORATIVE DISCHARGE SYSTEMS COMPARED, COMPARABLE OVERFLOW RATES, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Feedlot Size	Alternative Systems (OF-open field) (PL-playa lake) (E-evaporative)
5,000 Head	OF<PL<E
10,000 Head	OF<PL<E
25,000 Head	PL<OF<E

for the 5,000 and 10,000 head model feedlots.

Annual Costs

Annual costs for the various collection and disposal modifications for the three model feedlots include part or all of the following: depreciation, interest on investment, electricity, maintenance and taxes. Consequently, annual costs can be defined as the sum of annual operating costs and annualized fixed costs. Each cost component is considered in turn in this section.

Depreciation

Specific equipment items will have different spans of operating life. Thus, depreciation rates will vary from item to item. Depreciation rates used in this study were based upon estimated equipment life as listed in the United States Federal Tax Guide and on recommendations made by a local accounting firm (See Table 13).

TABLE 13

SELECTED DEPRECIATION RATES, EQUIPMENT COMPONENTS AND LAND IMPROVEMENTS, TEXAS HIGH PLAINS, 1968

Items	Years of Life	Yearly Depreciation (percent)
Sprinklers	5	20.0
Pump and Motor Combination	8	12.5
Aluminum Pipe	10	10.0
Underground Plastic Pipe	10	10.0
Land Improvements	20	5.0

Source: Estimates are from the Federal Tax Guide, 1968 (Chicago: Commerce Clearing House, Inc., 1968), Vol. 1, pp. 1, 1347, and Edward E. Merriman and Company, Lubbock, Texas.

Interest on Investment

Interest paid on investment is a cost to the feedlot for the use of capital or for the use of resources. The magnitude of the interest charge is determined by what capital would bring in its best alternative use. The rate of return is usually determined by the going rate of interest. A 3 percent rate of interest was selected for the land component in this study on the basis that this is approximately the return that might be expected for operations involving a similar degree of risk. The rate of interest selected for investment in land improvements and mechanical facilities was 6 percent. It was assumed that investment will decrease to zero at the end of the useful life of an asset for all investments other than land, consequently, the interest rate was applied to one-half the original investment in land improvements and mechanical equipment.

Electricity

Electrical costs depend on the quantity of electrical energy consumed which in turn is a function of the size of the electric motor used and the number of operating hours. One horsepower, theoretically speaking, is equivalent to .746 kilowatt, but due to losses in mechanical efficiency, a more realistic and more generally used estimate equates 1 horsepower to 1 kilowatt. The number of operating hours for the pumping unit depends on the number of gallons of water discharged from the system which in turn is a function of the size of the collection basin, the discharge rate, and the quantity of precipitation.

Electrical rate schedules are usually constructed such that the price per unit of electrical energy decreases as the total quantity of energy consumed increases. Consequently, the price per unit of electrical energy will depend on the quantity of energy currently consumed by the three model feedlots. Estimates of the marginal electrical rates for additional electricity consumed by the runoff control operation were provided by a local utility firm. Electrical costs for the 5,000 head feedlot runoff control system amounted to .8 cents per kwh for each additional kwh used per month. In contrast to the 5,000 head model feedlot, the 10,000 head lot and the 25,000 head lot were assessed a demand charge in addition to the energy charge. The demand charge is a device utilized by utility companies to spread the costs of generating capacity equitably among small and large energy consumers. A local utility company indicated that a demand charge of $1.25 per kw for all additional kw of demand per month would be appropriate for the 10,000 and 25,000 head model feedlots. Energy charges for these larger feedlots were estimated at .8 cents and .55 cents per kwh for each additional kwh used by the 10,000 and 25,000 head feedlots, respectively.

Maintenance

System maintenance requirements were divided into two components for convenience in analyzing the various maintenance costs involved. These two components and their associated costs are (1) maintenance of mechanical equipment and (2) removal of organic material from the collection basin.

Cost of maintaining mechanical equipment will vary between feedlots because of variations in individual management decisions, accounting procedures, and the type and quality of initial installation. A figure of five percent of the initial dollar investment was selected as representative of the annual repair and maintenance cost on equipment items for each feedlot. This rate is slightly higher than that used in other studies, however, this upward bias is somewhat compensated by the additional assumption that labor required to check on the system while it is in operation is a maintenance function. This latter function was not otherwise charged against the collection system except for its inclusion in the higher maintenance rate.

Quantities of suspended solids deposited in a collection system are increased during warm weather, or under conditions of lower rainfall and under moist conditions.[8] Feedlot suspended solids concentrations in simulated rainfall studies at Texas Technological College ranged from 3400 to 13400 Mg/l with a mean of 8950 Mg/l. In this study the mean value of suspended solids was used to compute the average annual amount of suspended solids discharged into the collection system. Average pounds of suspended solids per year per acre of feedlot discharged into the collection system were computed from the equation:

$$TS = G \times 8.33 \times \frac{8950}{1,000,000}$$

$$= .075\ G \qquad (7)$$

where:
TS = pounds of total suspended solids/acre
G = gallons of runoff/acre
8.33 = weight of one gallon of water in pounds

Annual average rainfall subjected to runoff was estimated at 11.79 inches, therefore, using equation 1, average annual runoff amounts to 9.91

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[8] Miner, J. R., et.al. "Cattle Feedlot Runoff, Its Nature and Variation," Journal Water Pollution Control Federation, Vol. 38, No. 10, 1966, pp. 1587-8.

inches of rainfall equivalent. The average quantity of runoff per acre per year amounts to 269,116 gallons. Estimated total suspended solids deposited in the collection basin were computed according to equation 7 as follows:

$$\begin{aligned} TS &= .075\ G \\ &= .075\ (269{,}116) \\ &= 20184 \text{ lbs. per acre} \end{aligned}$$

It was assumed that approximately 1/3 of the total solids carried to the collection basin would settle out. Since the holding time for the mechanical discharge system is relatively short, it was also assumed that biological activity with respect to these solids will be minimal such that all suspended solids that settle out must be removed. In contrast, the evaporative discharge system envisaged a condition under which some biological activity occurred. Consequently, it was estimated that 1/4 of the total suspended solids deposited in the basin must be removed or conversely 1/12 of the suspended solids settling out would be removed by biological activity. For example, an average of 403,680 pounds of total solids would be carried to the collection basin from a 5,000 head feedlot (20 acres) each year. On this basis, a mechanical discharge system will require removal of 134,560 pounds of organic material and an evaporative discharge system the removal of 100,920 pounds of organic material.

Pounds of total suspended solids discussed above are expressed in dry weight. The amount of water contained in this solid waste will vary between cleanings. It was estimated that total pounds of organic material removed will consist on the average of 60 percent solids and 40 percent water yielding approximately 224,267 pounds and 168,000 pounds of organic material to be removed from the mechanical and evaporative discharge systems, respectively for a 5,000 head feedlot.

The cost of custom hauling and spreading this organic material on farmland within a radius of 3 miles from the feedlot was determined at $1.50 per ton for amounts less than 2,000 tons and at $1.00 per ton for amounts in excess of 2,000 tons. It was assumed that manure from the feedlot will be removed concurrently with the cleaning of the collection basin such that the total quantity removed will approximate 1,000 to 2,000 tons and, hence, will qualify for at least the $1.50/ton rate.

Taxes

Property in the State of Texas is subject to state and local taxes. The additional tax assessment resulting from the pollution control operation was based on the initial cost of land, construction cost of facilities and acquisition cost of the equipment. State and county taxes are levied at the rate of $1.36 per $100.00 of appraised value which in turn constitutes 40 percent of the actual value. School taxes are levied at the rate of $1.50 per $100.00 of appraised value which in turn constitutes approximately 66 2/3 percent of the actual value. Property tax rates used in this study were obtained from the Lubbock County Tax Assessor-Collector.

Annual Cost Summary

The open field disposal modification experienced annual costs of $776.00, $1,157.00, and $2,429.00 for the 5,000, 10,000, and 25,000 head feedlots, respectively for a minimum protection collection system (2" system, .2" discharge rate) (See Table 14). Annual costs for a maximum protection collection system (6" system, .6" discharge rate) for the three model feedlots amounted to $1,065, $1,820, and $4,456 for 5,000, 10,000, and 25,000 head feedlots, respectively. Annual costs for the playa lake disposal modification at the minimum protection level amounted to $942, $1,234, and $2,101 for the 5,000, 10,000 and 25,000 head feedlots, respectively. Annual costs for a maximum protection collection system (playa lake disposal modification) for the three model feedlots amounted to $1,241, $1,720, $3,165 for the 5,000, 10,000, and 25,000 head feedlots, respectively.

Annual costs for maximum protection evaporative discharge systems (16" system) amounted to $788, $1441, and $3487 for the 5,000, 10,000, and 25,000 head model feedlots, respectively (See Table 15). Strict cost comparisons between maximum protection mechanical system and maximum protection evaporative systems are, however, not valid since the degree of protection provided differs measurably between mechanical and evaporative systems.

TABLE 14

ANNUAL COSTS, MECHANICAL DISCHARGE SYSTEMS, OPEN FIELD AND PLAYA LAKE DISPOSAL MODIFICATIONS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size In Rainfall Equivalent Inches		Open Field			Playa Lake		
Basin Capacity	Discharge Rate/24 hrs.	5000 Head	10,000 Head	25,000 Head	5000 Head	10,000 Head	25,000 Head
		Dollars					
2	.2	776	1157	2429	942	1234	2101
	.4	804	1327	2796	970	1326	2234
	.6	868	1436	3298	1065	1355	2496
3	.2	809	1288	2587	981	1305	2298
	.4	840	1409	3106	1004	1397	2421
	.6	919	1522	3681	1099	1456	2671
4	.2	844	1357	2761	1015	1368	2458
	.4	879	1477	3279	1037	1475	2580
	.6	953	1675	4091	1133	1580	2830
5	.2	878	1428	2930	1049	1438	2625
	.4	913	1547	3460	1070	1545	2747
	.6	987	1745	4273	1167	1650	2997
6	.2	952	1498	3098	1126	1508	2792
	.4	986	1617	3633	1145	1615	2914
	.6	1065	1820	4456	1241	1720	3165

TABLE 15

ANNUAL COSTS, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size In Rainfall Equivalent Inches	Size		
	5,000 Head	10,000 Head	25,000 Head
Basin Capacity	Dollars		
12	653	1178	2793
13	688	1248	2966
14	720	1320	3137
15	752	1386	3313
16	788	1441	3487

SYSTEM SELECTION

Selection of the least cost runoff control system will depend on (1) the costs of constructing and operating the system and (2) the degree of protection desired. Since overflow can result in a penalty ranging from $50-$1000 per day imposed by the pollution control authorities, cost of overflow can be quantified by multiplying the number of overflows by expected penalties imposed. This latter figure, penalty for overflow, can be considered an additional cost of operating any system since all systems are subject to some overflow. A $1000 penalty rate was selected as the maximum penalty imposed and a $50 penalty rate was considered the minimum penalty imposed. A third or a variable penalty rate was also developed based on the number of overflows. This latter rate was designed to vary between $1000 and $50 as follows: 120 to 71 overflows, $1000; 70-41 overflows, $750; 40-21 overflows, $500; 20-11 overflows, $250; and 10-0 overflows, $50 (See Tables 16 and 17).

The sum of overflow cost and annual costs for any system constitutes the total expected costs of that system (See Tables 18, 19, and 20). As the size of the system increases, annual costs increase. Conversely, however, the larger the system, the lower the probability of overflow and the smaller the overflow cost. Figure 2 illustrates the method used for selecting the least cost system. The figure indicates that as system size increases, overflow costs (A) decrease and annual costs (B) increase. When these two cost components are combined (C) overflow costs decrease faster than annual costs increase such that total expected costs decline with increases in system size and reach a minimum for that system having a basin capacity of 5 inches of rainfall equivalent. Overflow costs are high for smaller systems and low levels of protection. Beyond a certain capacity (5 inches), annual costs increase at a faster rate than overflow costs such that total expected costs for the system increase.

Least Cost System - Open Field Disposal Modification

At the $1000 penalty level the 5"-.4", 6"-.2", and 5"-.2" systems achieved minimum costs for the 5,000, 10,000 and 25,000 head model feedlots respectively (See Table 18). The number of overflows for these systems amounted to 4 overflows for the 5,000 and 10,000 head model feedlot or one overflow every 10 years, and 8 overflows for the 25,000 head model feedlot, one overflow every 5 years. In each case, total expected costs, including overflow costs at the $1000 penalty level for each of the three model feedlots, decreased rather rapidly as system size increased, reached a minimum and then increased.

The $50 penalty level yields an entirely different set of results from the $1000 penalty level. The data in Table 20 indicate that a 3"-.2" system is the least cost system for a 5,000 head feedlot at the $50 penalty level. Similarly, at this same penalty level, a 2"-.2" system yields minimum costs of $1,249 and $2,521 for the 10,000 and 25,000 head feedlots, respectively. The least cost system (3"-.2") at the $50 penalty level for the 5,000 head feedlot incurred 36 overflows in the 41 year period or approximately one overflow per year. The least cost system for the 10,000 and 25,000 head feedlots at the $50 penalty level experienced 75 overflows in the 41 year period or approximately 2 overflows per year. Annual cost differences between least cost systems at the $50 penalty level and least cost systems at the $1000 penalty level amounted to $104, $341 and $204 for the 5,000, 10,000 and 25,000 head

TABLE 16

NUMBER OF OVERFLOWS AND RELATIVE COST, ($1000, $50 AND VARIABLE PENALTY LEVELS)

MECHANICAL DISCHARGE SYSTEMS, BY SYSTEM SIZE, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Number of Overflows	Penalty Levels					
			$1000/day		$50/day		$Variable/day	
Basin Capacity	Discharge Rate/24 hrs.	(in 41 year period)	Total	Annual	Total	Annual	Total	Annual
			-----------	Dollars	-----------			
2	.2	75	75,000	1829	3750	91	75,000	1829
	.4	59	59,000	1439	2950	72	44,250	1079
	.6	50	50,000	1220	2500	61	37,500	915
3	.2	36	36,000	878	1800	44	18,000	498
	.4	29	29,000	707	1450	35	14,500	353
	.6	19	19,000	463	950	23	4,750	116
4	.2	17	17,000	415	850	21	4,250	104
	.4	11	11,000	268	550	13	2,750	67
	.6	8	8,000	159	400	10	400	10
5	.2	8	8,000	159	400	10	400	10
	.4	4	4,000	98	200	5	200	5
	.6	4	4,000	98	200	5	200	5
6	.2	4	4,000	98	200	5	200	5
	.4	4	4,000	98	200	5	200	5
	.6	3	3,000	73	150	4	150	4

TABLE 17

NUMBER OF OVERFLOWS AND RELATIVE COSTS, ($1000, $50 AND VARIABLE PENALTY LEVELS), EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE

System Size in Rainfall Equivalent Inches		Penalty Levels					
		$1000/day		$50/day		$Variable/day	
Basin Capacity	Number of Overflows in 41 Year Period	Total	Annual	Total	Annual	Total	Annual
		Dollars					
12	111	111,000	2707	5550	135	111,000	2707
13	83	83,000	2024	4150	101	83,000	2024
14	58	58,000	1415	2900	71	43,000	1061
15	16	16,000	390	800	20	4,000	976
16	7	7,000	171	350	9	350	9

TABLE 18

TOTAL EXPECTED COSTS, OPEN FIELD DISPOSAL MODIFICATION ($1000, $50 AND VARIABLE PENALTY LEVELS), BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		5,000 Head			10,000 Head			25,000 Head		
Basin Capacity	Discharge Rate/24 hrs.	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable
		Dollars								
2	.2	2606	868	2606	2897	1249	2987	4259	2521	4259
	.4	2243	876	1883	2767	1400	2407	4236	2869	3876
	.6	2088	930	1784	2656	1498	2352	4518	3360	4214
3	.2	1687	854	1249	2166	1332	1727	3465	2631	3026
	.4	1548	876	1194	2117	1444	1762	3814	3142	3460
	.6	1383	943	1036	1985	1545	1638	4145	3705	3798
4	.2	1259	864	948	1772	1378	1462	3176	2782	2865
	.4	1148	893	946	1746	1491	1558	3548	3293	3347
	.6	1149	963	963	1871	1685	1685	4286	4101	4101
5	.2	1074	888	888	1623	1438	1438	3125	2913	2940
	.4	1011	918	918	1645	1552	1552	3553	3465	3465
	.6	1085	992	992	1843	1751	1751	4371	4278	4278
6	.2	1050	957	957	1596	1504	1504	3196	3103	3103
	.4	1085	992	992	1715	1622	1622	3731	3639	3639
	.6	1139	1069	1069	1894	1825	1825	4529	4460	4460

TABLE 19

TOTAL EXPECTED COSTS, PLAYA LAKE DISPOSAL MODIFICATION, ($1000, $50 AND VARIABLE PENALTY LEVELS), BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		5,000 Head			10,000 Head			25,000 Head		
Basin Capacity	Discharge Rate/24 hrs.	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable
		Dollars								
2	.2	2772	1034	2772	3064	1326	3064	3931	2193	3931
	.4	2409	1042	2049	2766	1399	2406	3673	2306	3313
	.6	2285	1127	1981	2575	1417	2271	3716	2558	3412
3	.2	1860	1026	1421	2183	1349	1744	3176	2342	2737
	.4	1711	1039	1357	2104	1432	1750	3128	2456	2774
	.6	1563	1123	1216	1920	1480	1573	3135	2694	2687
4	.2	1430	1036	1120	1783	1389	1473	2873	2479	2562
	.4	1306	1051	1105	1743	1489	1542	2849	2594	2647
	.6	1329	1143	1143	1775	1590	1590	3026	2840	2840
5	.2	1245	1059	1059	1634	1448	1448	2821	2635	2635
	.4	1168	1075	1076	1643	1550	1505	2845	2752	2752
	.6	1265	1172	1172	1748	1655	1655	3095	3003	3003
6	.2	1224	1131	1131	1606	1514	1514	2891	2798	2798
	.4	1243	1150	1150	1713	1620	1620	3013	2920	2920
	.6	1314	1245	1245	1793	1724	1724	3238	3169	3169

TABLE 20

TOTAL EXPECTED COSTS, EVAPORATIVE DISCHARGE SYSTEMS, ($1000, $50 AND VARIABLE PENALTY LEVELS), BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches Basin Capacity	5,000 Head			10,000 Head			25,000 Head		
	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable	$1000.00	$50.00	$Variable
	Dollars								
12	3361	789	3361	3886	1314	3886	5501	2929	5501
13	2713	790	2713	3273	1350	3273	4991	3068	4991
14	2135	791	1781	2735	1391	2381	4552	3208	4199
15	1143	772	1728	1777	1406	2362	3704	3333	4290
16	959	797	797	1612	1450	1450	3659	3496	3496

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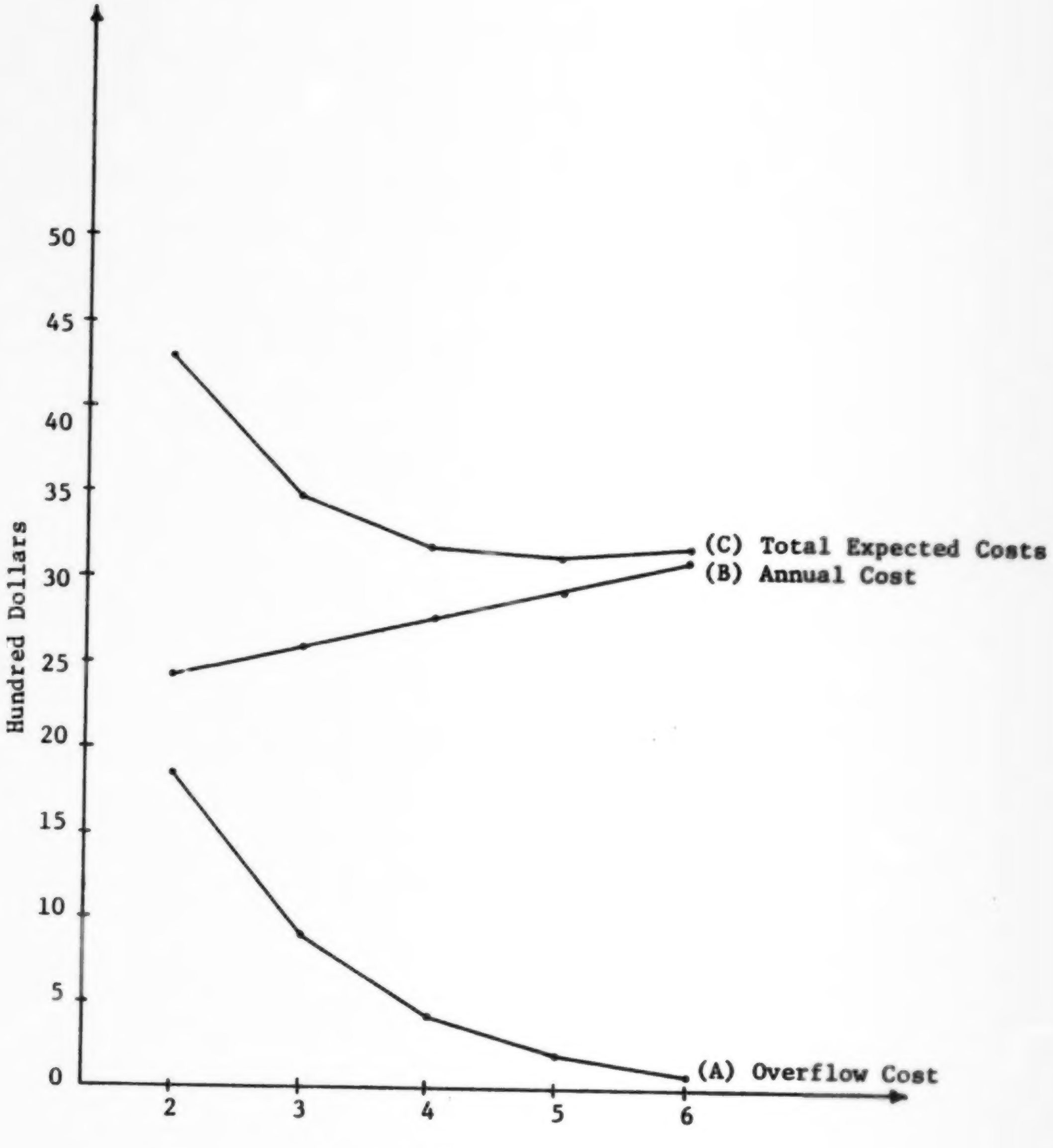

Figure 2. Annual Cost, Overflow Costs, and Total Expected Costs, Open Field Disposal Modification, .2 Inch Discharge Rate/24 hrs. (Rainfall Equivalent), $1000 Penalty Rate, 25,000 Head Model Feedlot.

feedlots, respectively. These differences in annual costs, when considered with the total investment in feedlot facilities and cattle, are so small as to almost preclude economic consideration. In brief, a much higher degree of overflow protection can be achieved with only a slight increase in annual costs.

Since the actual penalty level is unknown, a variable penalty level was included in the analysis. The analysis indicated that a 5"-.2" system would constitute a least cost system for the 5,000 and 10,000 head feedlots and that a 4"-.2" system would achieve least costs for the 25,000 head model feedlot under this variable penalty level. These latter least cost systems agree very closely in size and degree of protection with least cost systems indicated at the $1000 penalty level.

Least Cost System - Playa Lake Disposal Modification

Least costs for the playa lake disposal modification are achieved at the same system size and discharge rates as were achieved by the open field disposal modification at both the $1000 and $50 penalty levels (See Table 19). Similarly, least cost systems for the playa lake disposal modification computed at the variable penalty level were the same size as those developed from the open field disposal modification at the same penalty level for the three model feedlots.

Least Cost Evaporative Discharge Systems

Least costs for evaporative discharge systems, at the $1000 per day penalty level were achieved by a 16" system (See Table 20). Total expected costs for this 16" system amounted to $959, $1,612, and $3,659 for the 5,000, 10,000 and 25,000 head feedlots, respectively. The number of overflows for the system in turn amounted to 7 overflows for the 41 year period or an average of one overflow every 6 years. In contrast, at the $50 penalty level, the least cost facility was achieved by a 15" system for the 5,000 head model feedlot and a 12" system for the 10,000 and 25,000 head model feedlots. Total expected costs for these systems amounted to $772, $1,314, and $2,929 for the 5,000, 10,000 and 25,000 head model feedlots, respectively. The difference in annual costs between 15" and 16" systems for a 5,000 head feedlot amounts to $36. The 15" system overflows approximately once every 2 years, whereas a 16" system overflows approximately once in 6 years. Similarly, differences in annual costs between a 12" and 16" system amounts to $263 and $694 for the 10,000 and 25,000 head model feedlots, respectively. As in the case of the mechanical discharge systems (open field and playa lake disposal modifications) these differences, when considered together with the total investment in feedlot facilities and cattle, are so small as to preclude economic consideration.

Cost Comparisons - All Systems

Criteria for choosing between mechanical discharge systems and evaporative discharge systems are only partially economic. Among the systems considered, mechanical discharge systems provided a greater degree of protection (4 overflows for 5"-.4" and 6"-.2" systems) than evaporative discharge systems (7 overflows for 16" systems) at a slightly lower cost for the 5,000 and 10,000 head feedlots. The evaporative discharge system for the 25,000 head feedlot had slightly lower costs than the mechanical discharge systems with approximately the same number of overflows. However, evaporative discharge systems are so extensive relative to the amount of land required, that land availability may constitute a major problem. In view of the large land requirement for evaporative discharge systems, mechanical discharge systems which provide a high degree of protection at reasonably low cost and which utilize a minimum amount of land would seem to be preferrable (See Appendix A, Tables 3, 4, and 5).

In selecting between two mechanical discharge systems, open field or playa lake disposal modifications, the open field disposal modification achieved the lowest cost and provided a reasonable degree of protection except for the 25,000 head model feedlot. In this latter case, the open field disposal modification experienced slightly higher expected costs ($304 annually)_ than the playa lake disposal modification for the same degree of protection. If the distance to the playa lake appreciably exceeds 2500 feet, then the open field disposal modification would incur lower expected costs than the playa lake disposal modification for a 25,000 head feedlot. Table 21 summarizes that data on the least cost system (expected costs) for each disposal modification at all penalty levels for the three model feedlots. If society should refuse to accept any system experiencing an average of one or more overflows in a 4 year period then no system considered least cost at the $50 penalty level would be readily accepted by the Water Pollution Control authorities. Similarly, under a variable penalty level, the least cost system developed from the two mechanical discharge systems would also be unacceptable.

The difference in annual costs per head of annual cattle marketings between least cost facilities at the $1000 and variable penalty levels

TABLE 21

TOTAL INVESTMENT COSTS AND ANNUAL COSTS PER HEAD OF FEEDLOT CAPACITY AND PER HEAD OF ANNUAL MARKETINGS, SELECTED RUNOFF CONTROL SYSTEMS, THREE PENALTY LEVELS AND NUMBER OF OVERFLOWS PER SYSTEM, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Items	5,000 Head Feedlot			10,000 Head Feedlot		
	$1000	$50	$Variable	$1000	$50	$Variable
Open Field Modification						
Optimum Size System	5"-.4"	3"-.2"	5"-.2"	6"-.2"	2"-.2"	5"-.2"
No. of Overflows	4	36	8	4	75	8
Unit Cost						
Total Investment Cost						
Per hd. feedlot Cap.	$1.3615	1.1286	1.2920	1.0211	.6784	.9347
Per hd. Annual Mark.	$ .5446	.4514	.5168	.4084	.2713	.3738
Annual Cost						
Per hd. feedlot Cap.	$ .1826	.1619	.1756	.1499	.1158	.1428
Per hd. Annual Mark.	$ .0730	.0647	.0702	.0599	.0463	.0571
Playa Lake Modification						
Optimum Size System	5"-.4"	3"-.2"	5"-.2"	6"-.2"	2"-.2"	5"-.2"
No. of Overflows	4	36	8	4	75	8
Total Investment Cost						
Per hd. feedlot Cap.	$1.4111	1.3092	1.4726	1.0692	.7379	.9828
Per hd. Annual Mark.	$ .5644	.5236	.5890	.4276	.2951	.3931
Annual Cost						
Per hd. feedlot Cap.	$ .2104	.1963	.2099	.1509	.1235	.1439
Per hd Annual Mark.	$ .0856	.0785	.0839	.0603	.0495	.0575
Evap. Discharge Systems						
Optimum Size System	16"	15"	16"	16"	12"	16"
No. of Overflows	7	16	7	7	111	7
Total Investment Cost						
Per hd. feedlot Cap.	$1.7201	1.6299	1.7201	1.5682	1.2118	1.5682
Per hd. Annual Mark.	$ .6880	.6519	.6880	.6272	.4847	.6272
Annual Cost						
Per hd. feedlot Cap.	$ .1576	.1505	.1576	.1441	.1178	.1441
Per hd. Annual Mark.	$ .0630	.0625	.0630	.0576	.0471	.0576

TABLE 21 - Continued

Items	25,000 Head Feedlot		
	$1000	$50	$Variable
Open Field Modification			
Optimum Size System	5"-.2"	2"-.2"	4"-.2"
No. of Overflows	8	75	17
Unit Cost			
Total Investment Cost			
Per hd. feedlot Cap.	.7279	.4780	.6477
Per hd. Annual Mark.	.2911	.1912	.2590
Annual Cost			
Per hd. feedlot Cap.	.1172	.0971	.1104
Per hd. Annual Mark.	.0468	.0388	.0441
Playa Lake Modification			
Optimum Size System	5"-.2"	2"-.2"	4"-.2"
No. of Overflows	8	75	17
Total Investment Cost			
Per hd. feedlot Cap.	.6972	.4543	.6170
Per hd. Annual Mark.	.2789	.1817	.2167
Annual Cost			
Per hd. feedlot Cap.	.1050	.0840	.0983
Per hd. Annual Mark.	.0420	.0336	.0393
Evap. Discharge Systems			
Optimum Size System	16"	12"	16"
No. of Overflows			
Total Investment Cost			
Per hd. feedlot Cap.	1.4902	1.1352	1.4902
Per hd. Annual Mark.	.5961	.4541	.5961
Annual Cost			
Per hd. feedlot Cap.	.1395	.1117	.1395
Per hd. Annual Mark.	.0558	.0446	.0558

(5"-.4" and 5"-.2" respectively) is approximately one quarter of a cent for both the 5,000 and 10,000 head feedlots for both open field and playa lake disposal modifications. However, overflow occurs approximately once in 5 years for the least cost system at the variable penalty level compared to once in 10 years for the least cost system at the $1000 penalty level. That is, an increase in annual costs of one quarter of a cent per head marketed will reduce the number of overflows by one-half.

A 5"-.2" system was selected as the least cost facility for the 25,000 head feedlot for the playa lake and open field disposal modifications. Overflow for the 5"-.2" system occurred once every 5 years. This overflow could be reduced by one-half with a 6"-.2" system and a resulting increase in annual costs of less than a one cent per head of annual cattle marketings.

LIMITATIONS

This study leaves a residue of unanswered questions. Most important are those questions which relate to the effect and extent of seepage from the collection basin and feedlot surfaces and the percolation of water under the disposal area and feedlot. These questions are particularly important with respect to their potential as a source of pollution of underground water supplies.

Three other problems derived from animal waste management are odor, dust, and insect control. Odor is of particular interest since the collection of the runoff in a basin may cause an undesirable odor in the surrounding area. If the surrounding area is populated, then a feedlot manager may have to take measures to control this odor.

Estimates made in this study as to the percent of runoff that may be expected from a given level of precipitation were based on Kansas data and hence, may be biased due to the influence of environmental factors. Although the experiments in Kansas were extensive and were conducted under a variety of conditions, climatic and environmental factors may be sufficiently different from those experienced on the Texas High Plains to alter the size of the least cost system. Experiments should be conducted on the High Plains to determine the reliability of this data in terms of local conditions.

Calculations as to the amount of land required for the open field disposal modification were based on the water absorption capacity of the soil. The ability of High Plains soils to absorb large quantities of pollutant without adverse effects such as pollution of the underground water supply, nitrite ion accumulation, phosphorous ion accumulation or other effects, is unknown. A 50 percent safety factor was provided in determining land requirements for the open field disposal modification. Other studies have suggested land requirements for disposal in the amount of one quarter to one half of the area of the feedlot. In neither case are the parameters of the problem sufficiently well known to specify the land requirements with any real degree of accuracy.

APPENDIX A

TABLE 1

TOTAL CONSTRUCTION COST, MECHANICAL DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Feedlot and Collection Basin Capacity[a]	Collection Basin[b]	Diversion Terrace	Waterway	Total Construction Cost
	Dollars			
5,000 head				
2	2368	67	8	2445
3	2677	67	8	2753
4	2985	67	8	3061
5	3293	67	8	3370
6	3992	67	8	4068
10,000 head				
2	2908	105	22	3035
3	3528	105	22	3655
4	4142	105	22	4269
5	4756	105	22	4883
6	5371	105	22	5498
25,000 head				
2	4518	206	71	4795
3	6119	206	71	6396
4	7573	206	71	7850
5	9098	206	71	9375
6	10621	206	71	10898

[a] Collection basin capacity in rainfall equivalent inches

[b] Includes associated diversion terraces

APPENDIX A - Continued

TABLE 2

TOTAL CONSTRUCTION COST, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Feedlot and Collection Basin Capacity[a]	Collection Basin[b]	Diversion Terrace	Waterway	Total Construction Cost
	Dollars			
5,000 head				
12	4296	67	8	4372
13	4592	67	8	4668
14	4856	67	8	4932
15	5123	67	8	5199
16	5424	67	8	5500
10,000 head				
12	7541	105	22	7668
13	8126	105	22	8253
14	8713	105	22	8840
15	9269	105	22	9396
16	9354	105	22	9481
25,000 head				
12	17555	206	71	17832
13	19015	206	71	19292
14	20449	206	71	20726
15	21915	206	71	22192
16	23380	206	71	23657

[a] Collection basin capacity in rainfall equivalent inches

[b] Includes associated diversion terraces

APPENDIX A - Continued

TABLE 3

TOTAL ACREAGE REQUIREMENT, DIVERSION TERRACE, COLLECTION BASINS, AND DISPOSAL AREAS, OPEN FIELD DISPOSAL MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Land Requirement for Collection Basins and Diversion Terrace			Land Requirement for Disposal Area			Total Land Requirements		
Basin Capacity	Discharge Rate/24 hrs.	5,000 Head	10,000 Head	25,000 Head	5,000 Head	10,000 Head	25,000 Head	5,000 Head	10,000 Head	25,000 Head
		Acres								
2	.2	1.6	2.3	4.2	.3	.5	1.2	1.9	2.8	5.4
	.4	1.6	2.3	4.2	.5	1.0	2.4	2.1	3.3	6.6
	.6	1.6	2.3	4.2	.7	1.4	3.6	2.3	3.7	7.8
3	.2	1.8	2.8	5.2	.3	.5	1.3	2.1	3.3	6.5
	.4	1.8	2.8	5.2	.5	1.0	2.6	2.3	3.8	7.8
	.6	1.8	2.8	5.2	.8	1.5	3.9	2.6	4.3	9.1
4	.2	2.0	3.0	6.1	.3	.6	1.4	2.3	3.6	7.5
	.4	2.0	3.0	6.1	.6	1.1	2.7	2.6	4.1	8.8
	.6	2.0	3.0	6.1	.8	1.6	4.1	2.8	4.6	10.2
5	.2	2.2	3.5	7.2	.3	.6	1.4	2.5	4.1	8.6
	.4	2.2	3.5	7.2	.6	1.1	2.8	2.8	4.6	10.0
	.6	2.2	3.5	7.2	.8	1.6	4.2	3.0	5.1	11.4
6	.2	2.5	4.0	8.0	.3	.6	1.4	2.8	4.6	9.4
	.4	2.5	4.0	8.0	.6	1.1	2.9	3.1	5.1	10.9
	.6	2.5	4.0	8.0	.9	1.7	4.3	3.4	5.7	12.3

APPENDIX A - Continued

TABLE 4

TOTAL ACREAGE REQUIREMENT, DIVERSION TERRACES AND COLLECTION BASINS, PLAYA LAKE MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS

System Size in Rainfall Equivalent Inches		Feedlot Size		
Basin Capacity	Discharge Rate/24 hrs.	5,000 Head	10,000 Head	25,000 Head
		Acres		
2	.2	1.6	2.3	4.2
	.4	1.6	2.3	4.2
	.6	1.6	2.3	4.2
3	.2	1.8	2.8	5.2
	.4	1.8	2.8	5.2
	.6	1.8	2.8	5.2
4	.2	2.0	3.0	6.1
	.4	2.0	3.0	6.1
	.6	2.0	3.0	6.1
5	.2	2.2	3.5	7.2
	.4	2.2	3.5	7.2
	.6	2.2	3.5	7.2
6	.2	2.5	4.0	8.0
	.4	2.5	4.0	8.0
	.6	2.5	4.0	8.0

TABLE 5

TOTAL ACREAGE REQUIREMENT, DIVERSION TERRACES AND COLLECTION BASINS, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS

System Size in Rainfall Equivalent Inches	Feedlot Size		
	5,000 Head	10,000 Head	25,000 Head
	Acres		
12	4.3	7.8	19.9
13	4.6	8.4	21.6
14	4.9	9.3	23.3
15	5.2	9.9	25.3
16	5.5	10.7	27.2

APPENDIX B

TABLE 1

TOTAL INVESTMENT COST, (a) PER HEAD OF FEEDLOT CAPACITY AND (b) PER HEAD OF ANNUAL MARKETINGS, OPEN FIELD DISPOSAL MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Feedlot Size					
		5,000 Head		10,000 Head		25,000 Head	
Basin Capacity	Discharge Rate/24 hrs.	(a)	(b)	(a)	(b)	(a)	(b)
		Dollars					
2	.2	1.0470	.4188	.6784	.2713	.4780	.1912
	.4	1.0982	.4392	.7648	.3059	.5673	.2269
	.6	1.1873	.4749	.8147	.3258	.6613	.2645
3	.2	1.1286	.4514	.7691	.3076	.5669	.2267
	.4	1.1826	.4730	.8571	.3428	.6670	.2668
	.6	1.2912	.5164	.9147	.3658	.7672	.3069
4	.2	1.2104	.4841	.8483	.3393	.6477	.2590
	.4	1.2798	.5119	.9362	.3744	.7480	.2992
	.6	1.3729	.5491	1.0369	.4147	.8700	.3480
5	.2	1.2920	.5168	.9347	.3738	.7279	.2911
	.4	1.3615	.5446	1.0226	.4090	.8329	.3331
	.6	1.4545	.5818	1.1235	.4493	.9551	.3820
6	.2	1.4617	.5846	1.0211	.4084	.8080	.3232
	.4	1.5311	.6124	1.1091	.4436	.9162	.3664
	.6	1.6397	.6559	1.2177	.4870	1.0401	.4160

APPENDIX B - Continued

TABLE 2

TOTAL INVESTMENT COST, (a) PER HEAD OF FEEDLOT CAPACITY AND (b) PER HEAD OF ANNUAL MARKETINGS, PLAYA LAKE DISPOSAL MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Feedlot Size					
		5,000 Head		10,000 Head		25,000 Head	
Basin Capacity	Discharge Rate/24 hrs.	(a)	(b)	(a)	(b)	(a)	(b)
		Dollars					
2	.2	1.2250	.4900	.7379	.2951	.4543	.1817
	.4	1.2478	.4991	.7879	.3151	.4776	.1910
	.6	1.3478	.5391	.7692	.3184	.5130	.2052
3	.2	1.3092	.5236	.8250	.3299	.5407	.2162
	.4	1.3294	.5317	.8750	.3499	.5586	.2234
	.6	1.4294	.5717	.8912	.3564	.5975	.2390
4	.2	1.3909	.5563	.8964	.3585	.6170	.2467
	.4	1.4111	.5644	.9498	.3799	.6350	.2540
	.6	1.5111	.6044	1.0002	.4000	.6738	.2695
5	.2	1.4726	.5890	.9828	.3931	.6972	.2789
	.4	1.4928	.5971	1.0362	.4144	.7152	.2860
	.6	1.5928	.6371	1.0866	.4346	.7540	.3016
6	.2	1.6422	.6569	1.0692	.4276	.7774	.3109
	.4	1.6624	.6649	1.1226	.4490	.7953	.3181
	.6	1.7624	.7049	1.1730	.4692	.8342	.3336

APPENDIX B - Continued

TABLE 3

TOTAL INVESTMENT COST, (a) PER HEAD OF FEEDLOT CAPACITY, AND (b) PER HEAD ANNUAL MARKETINGS, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches	Feedlot Size					
	5,000 Head		10,000 Head		25,000 Head	
	(a)	(b)	(a)	(b)	(a)	(b)
	Dollars					
12	1.3745	.5498	1.2118	.4847	1.1352	.4541
13	1.4636	.5854	1.3003	.5201	1.2236	.4894
14	1.5465	.6186	1.3941	.5576	1.3110	.5244
15	1.6299	.6519	1.4796	.5918	1.4017	.5606
16	1.7201	.6880	1.5682	.6272	1.4902	.5961

APPENDIX B - Continued

TABLE 4

ANNUAL COST, (a) PER HEAD OF FEEDLOT CAPACITY, AND (b) PER HEAD OF ANNUAL MARKETINGS, PLAYA LAKE, DISPOSAL MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Feedlot Size					
		5,000 Head		10,000 Head		25,000 Head	
Basin Capacity	Discharge Rate/24 hrs.	(a)	(b)	(a)	(b)	(a)	(b)
		Dollars					
2	.2	.1885	.0754	.1235	.0493	.0840	.0336
	.4	.1940	.0776	.1327	.0530	.0893	.0357
	.6	.2131	.0852	.1356	.0542	.0998	.0399
3	.2	.1963	.0785	.1305	.0522	.0919	.0367
	.4	.2008	.0803	.1397	.0558	.0968	.0387
	.6	.2199	.0879	.1457	.0582	.1068	.0427
4	.2	.2031	.0812	.1369	.0547	.0983	.0393
	.4	.2075	.0830	.1475	.0590	.1032	.0412
	.6	.2267	.0906	.1580	.0632	.1132	.0452
5	.2	.2099	.8039	.1439	.0575	.1050	.0420
	.4	.2140	.0856	.1545	.0618	.1099	.0439
	.6	.2335	.0934	.1650	.0660	.1199	.0479
6	.2	.2252	.0900	.1509	.0603	.1117	.0446
	.4	.2290	.0916	.1615	.0646	.1165	.0466
	.6	.2482	.0992	.1720	.0638	.1266	.0506

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APPENDIX B - Continued

TABLE 5

ANNUAL COST, (a) PER HEAD OF FEEDLOT CAPACITY AND (b) PER HEAD OF ANNUAL MARKETINGS, OPEN FIEL DISPOSAL MODIFICATION, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

System Size in Rainfall Equivalent Inches		Feedlot Size					
		5,000 Head		10,000 Head		25,000 Head	
Basin Capacity	Discharge Rate/24 hrs.	(a)	(b)	(a)	(b)	(a)	(b)
		Dollars					
2	.2	.1552	.0621	.1158	.0463	.0971	.0388
	.4	.1608	.0643	.1328	.0531	.1118	.0447
	.6	.1737	.0695	.1437	.0574	.1319	.0527
3	.2	.1619	.0647	.1288	.0515	.1034	.0413
	.4	.1681	.0672	.1409	.0563	.1242	.0497
	.6	.1839	.0735	.1522	.0608	.1472	.0589
4	.2	.1688	.0675	.1358	.0543	.1104	.0441
	.4	.1758	.0703	.1477	.0590	.1311	.0524
	.6	.1907	.0762	.1675	.0670	.1636	.0654
5	.2	.1756	.0702	.1428	.0571	.1172	.0468
	.4	.1826	.0730	.1547	.0618	.1384	.0553
	.6	.1974	.0789	.1746	.1698	.1709	.0683
6	.2	.1904	.0761	.1499	.0599	.1239	.0495
	.4	.1973	.0789	.1618	.0647	.1453	.0581
	.6	.2131	.0852	.1821	.0728	.1782	.0712

APPENDIX B - Continued

TABLE 6

ANNUAL COSTS, (a) PER HEAD OF FEEDLOT CAPACITY, AND (b) PER HEAD OF ANNUAL MARKETINGS, EVAPORATIVE DISCHARGE SYSTEMS, BY SYSTEM SIZE, THREE MODEL FEEDLOTS, TEXAS HIGH PLAINS, 1968

Size System in Rainfall Equivalent Inches	Feedlot Size					
	5,000 Head		10,000 Head		25,000 Head	
	(a)	(b)	(a)	(b)	(a)	(b)
	Dollars					
12	.1306	.0522	.1178	.0471	.1117	.0446
13	.1376	.0550	.1248	.1499	.1186	.0474
14	.1440	.0576	.1330	.0528	.1255	.0502
15	.1505	.0625	.1386	.0554	.1325	.0530
16	.1576	.0630	.1441	.0576	.1395	.0558